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General News

Better-matched Cochineal Biotype Nails Killer Cactus

Eight years ago, Helmuth Zimmermann promised his wife that he would find a way to curb the invasiveness of the cactus weed, *Cylindropuntia fulgida* var. *fulgida* (*Cff*). The occasion was a visit to the town of Douglas, in the Northern Cape Province of South Africa, where they found dead rabbits and small antelopes impaled on the terrible spines of the invasive cactus, and livestock that had become covered in the spines to the point where they were unable to walk. It was not easy to fulfill the promise, but at last the long-desired moment seems to have arrived.

Cff is a branched, jointed cactus with long, dense, whitish spines. It belongs to the subfamily Opuntioideae, generally known as 'chollas', and occurs naturally in the Sonora desert of Mexico and the southern USA, where it is commonly known as the chain-fruit cholla or the jumping cholla – the latter in reference to the ease with which its cladodes attach themselves to animals or humans brushing past the plant. It was probably imported into South Africa as an ornamental, at least as early as the 1940s, but is now encroaching upon natural pastoral land and conservation areas in the warm, arid parts of the country. The worst infestations occur near Douglas and Kimberley (Northern Cape Province), and on both sides of the Zimbabwean border at Beit Bridge near Musina (Limpopo Province). Herbicidal control of the problem cactus, using first picloram and later MSMA, has been in practice in South Africa since the late 1970s, but without much success. The costs involved in this control method were prohibitive, particularly for the low-value land on which many of the infestations occurred. Biological control was regarded as the best alternative, based on the large number of cactus weeds in various countries that are under effective biological control. Cochineal insects (Hemiptera: Dactylopiidae), which have been used in various biocontrol projects in South Africa, were known to be highly restricted in their host range and potentially very damaging, which made these sap-sucking insects the first choice for introduction against chain-fruit cholla.

The first hurdle in the way of effective control of *Cff* was its initial misidentification in South Africa as rosea cactus, *Cylindropuntia rosea*. It was known from the literature that the cochineal insect, *Dactylopius tomentosus*, was a damaging natural enemy of *C. rosea* in its native home, Mexico. This insect species was already present in South Africa, having been introduced during the 1970s via Australia as an effective biocontrol agent of a closely related cactus weed, *Cylindropuntia imbricata*. Consequently, the weedy '*C. rosea*' in the Northern Cape was inoculated with cochineal insects collected from the nearest *C. imbricata* plants. The insects persisted on the inoculated plants, but were unable to damage them sufficiently.

An attempt was then made to find a better-matched cochineal population by introducing a culture of *D. tomentosus* from *C. rosea* growing in its natural habitat in central Mexico, but again the insects and the target weed seemed to be incompatible.

This raised the suspicion that a cholla species other than *C. rosea* might be involved. During a visit to Mexico, Helmuth Zimmermann became convinced that the species in question was the chain-fruit cholla (*Cff*), although no records existed in South Africa of cactus plants bearing chain-fruits, which are one of the characteristics of *Cff*. A PhD student, Catherine Mathenge (then still known under her maiden name Githure), became involved at this stage, and compared the performance and specificity of the cochineal insects, confirming their incompatibility (see article by Catherine Mathenge and Paul Holford, this issue, below). During a visit to an infestation of the problem cactus on the Zimbabwean side of the Limpopo River, where the cactus is not subject to the chemical control regime that was mandatory in South Africa, Helmuth Zimmermann, Catherine Mathenge and John Hoffmann indeed found some man-sized specimens of the cactus to have chain-fruits. This confirmed the identity of the problem cactus in both South Africa and Zimbabwe as *Cff*.

Now it was clear that the Sonora desert of Mexico and Arizona, the natural home of *Cff*, would have to be surveyed for effective biocontrol agents. A culture of the cochineal, *D. tomentosus*, was collected from the target cactus in Arizona, but Helmuth Zimmermann then stumbled upon a cochineal on a cactus species, *Cylindropuntia cholla*, in Baja California Sur, Mexico, which is very similar to *C. fulgida* var. *mamillata*. He brought both cochineal cultures to South Africa for comparison. Catherine Mathenge conducted research on the biology, performance and host specificity of these and other cultures of the cochineal, *D. tomentosus*, on the South African weedy *C. fulgida* as well as a selection of closely related cactus species (see article by Mathenge and Holford, below). Surprisingly, the cochineal from Baja California Sur turned out to be the most damaging to chain-fruit cholla. Meanwhile Catherine Mathenge relocated to Australia.

It was only during 2007, when the *Working for Water* (WfW) Programme of the Department of Water Affairs and Forestry agreed to fund the revival of the biocontrol project against *Cff*, that a fresh culture of *D. tomentosus* could be collected from *C. cholla* in Baja California Sur. Helmuth Zimmermann had since retired, but remained involved in the project, which was now managed by Hildegard Klein. The introduced cochineal culture was cleared of predators and contaminants under quarantine conditions at Rietondale, Pretoria, and mass reared to obtain sufficient numbers for release.

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The first release of the new cochineal biotype in South Africa was made during October 2008, near Douglas in the Northern Cape by Debbie Sharp from WfW. A month later, on 18 November 2008, cochineal-infested cactus cladodes were attached to a number of large chain-fruit cholla plants growing in the dry bed of the Limpopo River near the border post at Beit Bridge, again with the assistance of WfW. A clearing team of WfW has been active in this area for several years, combating the cactus chemically as part of a public works programme.

On 18 March 2009 (exactly four months after release, during which the insects might have completed two generations), Hildegard Klein and Helmuth Zimmermann, together with five employees of the WfW Programme, visited the release site again, hoping to find some early signs of insect establishment. To their utter amazement the cochineal had not only become established on each of the inoculated plants, but the inoculated plants were virtually covered from top to bottom with clusters of *D. tomentosus* females. The branches were hanging, and many of the lower cladodes on these plants were dead and had dropped off the plants. What is more, the insects had already started dispersing, with most of the *Cff* plants within a radius of 3 m or more from the inoculated plants infested, which is a relatively large distance for the crawlers (first instar nymphs) of the sedentary, flightless insects to cover. Many small plants consisting of only a few cladodes had already died and young plants less than 1 m tall were collapsing.

It is already evident that the WfW clearing team will have to make some serious adjustments to their chemical control programme to take full advantage of this new cochineal. The team members will probably in future be harvesting cochineal-infested cactus cladodes and redistributing them, instead of applying herbicides.

The rate of population build-up and dispersal of the cochineal biotype, as well as its damage to the cactus, have exceeded all expectations. In the four months since its release in Musina it has achieved a level of success that is normally expected only after a year or more. It is expected to become one of South Africa's most spectacularly effective biocontrol projects. This exceptional performance by the cochineal should, however, not have come as a surprise, since it had been predicted by Catherine Mathenge. The population growth rate of the insects and their severe damage to the cactus might be ascribed to the fact that this is a 'new association' between an insect and a plant population that have not co-evolved or that have been separated for an extensive period of time. Had it not been for Catherine Mathenge's research, the particular cochineal biotype would probably not have been imported, and biocontrol of the cactus weed in South Africa might have remained mediocre.

As a result of the unexpectedly rapid development of the cochineal colony in Musina, we have missed the opportunity to witness the earliest stages in the establishment, population growth and dispersal of the insect, and to measure the early effect to the target weed. The immediate intention is therefore to select an area with a more evenly distributed infestation of *Cff* in the Northern Cape, where the cochineal is not yet present, and to make new releases that will be monitored earlier. There is also a need to establish official relations with the phytosanitary authorities in Zimbabwe, to ensure that this successful biocontrol agent reaches the large infestations of *Cff* on the Zimbabwean side of the border at Beit Bridge, which have already reached crisis levels, and where the local community is desperate for a solution to this cactus problem that is causing stock losses and devastating their pastures.

On a cautionary note: the devastation that *Cff* can cause to biodiversity was brought home once more by the pitiful sight of three dead Woodlands Kingfishers that had become impaled on the spines of cactus specimens a small distance from the cochineal release site. Zimbabweans living near Beit Bridge report that the cactus is a huge threat to livestock grazing as well as game in the area, and that not even rats can pass through some of the cactus thickets. Cactus collectors are urged to keep the invasive potential of cacti in mind in countries where they have no natural enemies, and to resist the temptation to plant introduced cacti on their property but, above all, not to discard them in such a way that they might escape into the wild.

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Host-specific Cochineal Biotypes in the Fight against Invasive Cactus Weeds in South Africa

The article by Hildegard Klein and Helmuth G. Zimmermann (this issue, above) describes the remarkable damage caused to the highly invasive cactus, chain-fruit cholla (*Cylindropuntia fulgida* var. *fulgida*; *Cff*), following a recent release of a biotype of the cochineal insect, *Dactylopius tomentosus,* in South Africa. The research work behind this success is the subject of this article.

Dactylopius tomentosus is known to be restricted to *Cylindropuntia* species. However, it was unexpected that it could thrive on *C. imbricata* in Australia and South Africa, and *C. rosea* in Mexico but failed to establish on *Cff* (at the time known as *C. rosea*) in South Africa (see article by Klein and Zimmermann, above). This raised questions regarding the identity of the weed species and the host specificity of *D. tomentosus,* and led to the initiation of the research project described in this article. Populations of *D. tomentosus* from different hosts and localities are hereafter referred to as provenances and named according to the host species from which they were collected.

Host-specificity tests were conducted involving two provenances of *D. tomentosus*: one collected from *C. imbricata* in South Africa (henceforth called the imbricata provenance) and one collected from *C. rosea* in Mexico (henceforth called the rosea provenance). These provenances were reared on both *C. imbricata* and the target weed, *Cff*. On the target weed, the imbricata provenance survived poorly and insects of the rosea provenance did not complete their life cycle. However, both populations thrived on *C. imbricata*. This remarkable finding led to a reassessment of the target weed which was subsequently identified as *Cylindropuntia fulgida* var. *fulgida*, whose native range is the Sonoran desert of Arizona and Mexico.

With the correct identification of the weed, the project undertook the first study of the biology of *D. tomentosus* revealing that this species exhibited some biological and morphological aspects that differed from those of its congeners[1]. The next task was to search for a *D. tomentosus* provenance with the potential to cause severe damage to, and successfully control *Cff*. Further exploration by Helmuth Zimmermann led to the collection and importation of *D. tomentosus* provenances from a number of *Cylindropuntia* taxa in the New World: *Cff* and *C. f.* var. *mamillata* in the Sonoran desert, *C. rosea* and *C. tunicata* from different localities in Mexico, and *C. cholla* from different localities in Baja California. Experiments were conducted in South Africa, at the Plant Protection Research Institute, Pretoria, to assess survival and performance of the provenances on *Cff*. These studies revealed significant differences between provenances in their performance on and damage to *Cff* [2]. A provenance (collected from *C. cholla*, the cholla provenance) with great potential to control *Cff* was identified and is the insect used for biocontrol as described in the article above by Klein and Zimmermann. The most surprising aspect of this provenance was that it came from *C. cholla* from Baja California, Mexico whereas provenances from the weed's native range performed poorly. This may be explained in terms of the 'new association' phenomenon in which insect populations that have not co-evolved with a target weed perform better than old associations.

Based on the observed subspecific differentiation in host specificity among *D. tomentosus* provenances towards *Cff* and *C. imbricata*, the research further explored the hypothesis of the occurrence of biotypes of this insect in relation to host plant species. The results of these studies showed that the provenances fell into three categories on any host: some thrived on a particular host, others survived poorly, whereas others died before completing their life cycles. These observations demonstrated the occurrence of host-affiliated biotypes.

Although the occurrence of biotypes had now been determined, the extent of their differentiation was still an outstanding issue. This warranted some attention: as *C. imbricata* and *Cff* occur in sympatry in some areas in South Africa, it is likely that the ranges of the two insect biotypes may overlap. Therefore, cross-breeding studies were conducted between the cholla and imbricata biotypes to assess their reproductive compatibility and the impact of hybridization on host specificity. The two biotypes cross-bred freely in the laboratory producing viable offspring that had similar or greater potential to cause damage to *Cff* and *C. imbricata* than their parents. The hybrid offspring were less host specific than their parents, implying that hybridization would not have a negative impact on biological control of either weed.

During this part of the study, a bias in hybrid performance towards their maternal parent host was observed indicating that host specificity may be genetically based. Genetic diversity among the biotypes was assessed by sequencing part of the mitochondrial cytochrome *c* oxidase subunit 1 gene. Sequences within a biotype were identical and biotypes from the same host species clustered together irrespective of place of origin. This provides further evidence for the existence of host-adapted biotypes in *D. tomentosus*.

These studies on *D. tomentosus* highlight the importance of considering the existence of biotypes when selecting insects for biological control, as the selection of an inappropriate biotype may lead to its failure in the field.

[1]Mathenge, C.W., Holford, P., Hoffmann, J., Spooner-Hart, R., Beattie, G.A.C. & Zimmermann, H.G. (2009) The biology of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae). *Bulletin of Entomological Research* (online 10 February 2009; doi: 10.1017/S0007485308006597).

[2]Mathenge, C.W., Holford, P., Hoffmann, J., Zimmermann, H.G., Spooner-Hart, R. & Beattie, G.A.C. (2009) Distinguishing suitable biotypes of *Dactylopius tomentosus* (Hemiptera: Dactylopiidae) for biological control of *Cylindropuntia fulgida* var. *fulgida* (Caryophyllales: Cactaceae) in South Africa. *Bulletin of Entomological Research* (online 23 March 2009; doi: 10.1017/S0007485309006671).

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Can Manipulations of Amphibians' Mutualistic Skin Bacteria Control a Lethal Skin Disease?

The current extinction crisis is not sparing amphibians. While habitat loss and destruction are the major causes of amphibian extinction, disease is also causing population declines. Chytridiomycosis is a skin disease of amphibians caused by the fungus *Batrachochytrium dendrobatidis* (*Bd*), and is the causal agent of population declines and extinctions in relatively pristine areas, such as national parks. This species was only described in 1999, yet we have learned quite a bit about its biology and ecology. *Bd* seems to have originated in South Africa and spread to other parts of the world on *Xenopus laevis*, the African clawed frog, which was exported for use in pregnancy tests[1]. Despite the pathogen's role in many amphibian species' decline and extinction, relatively little research has focused on how to control the disease in nature. Our research has focused on the ecology of amphibian skin in an attempt to limit the disease.

When *Bd* colonizes amphibian skin, it encounters transient and resident skin microbiota. We have found that many of the resident bacterial species inhibit *Bd* in laboratory challenge assays. Three of the inhibitory metabolites, 2,4-diacetylphloroglucinol from *Lysobacter gummosus* and violacein and indole-3-carboxaldehyde from *Janthinobacterium lividum*, have been identified from pure bacterial cultures[2]. In addition, these metabolites are found on some amphibians in nature in concentrations high enough to inhibit *Bd*. To our knowledge, amphibians do not produce these metabolites themselves, so it appears that their symbiotic skin bacteria are responsible.

We have shown through a 'bacterial removal' experiment that the resident microbes on the skins of *Plethodon cinerus*, red-backed salamanders, ameliorate the symptoms of chytridiomycosis. Individuals with their skin bacteria reduced by exposure to antibiotics had greater morbidity than those salamanders left with their skin bacteria unmanipulated. Bioaugmentation is a strategy whereby we *increase* the proportion of individuals with a species of anti-*Bd* bacteria already found on other members of the population. In a laboratory experiment, we added *J. lividum* to skins of the mountain yellow-legged frog, *Rana muscosa*, before exposure to *Bd*[3]. Those treated with *J. lividum* suffered no mortality or morbidity, whereas frogs exposed to *Bd* alone lost weight and died. Frogs that had *J. lividum* added to their skins had much higher concentrations of violacein on their skins, suggesting that this bacterial-produced metabolite inhibited *Bd*. Another exciting result from this experiment was that we were able to take *J. lividum* collected from a salamander species and successfully place it on a frog species, suggesting that some bacterial species can target the larger amphibian assemblage.

In nature, populations of *R. muscosa* that co-exist with *Bd* have a higher proportion of individuals with at least one culturable anti-*Bd* bacterial species. This result suggests a threshold effect analogous to herd immunity, whereby only a fraction of the population needs to be immunized in order for the disease to die out. A bioaugmentation strategy that can increase the proportion of amphibians with anti-*Bd* bacteria may prevent epidemic outbreaks of chytridiomycosis. There are a number of remaining challenges, such as how to implement a bioaugmentation strategy in nature. Currently, we are investigating transmission of bacteria from soil and water to amphibians. We already know that in the laboratory, we can introduce skin bacteria to amphibians from bacteria in artificial pond water. Of course, tests to make sure non-target species are not affected will be of critical importance. Recent work in agricultural contexts suggests that the introduction of beneficial bacteria does not affect the resident soil microbiota, which is encouraging.

An important component of amphibian conservation efforts is the creation of survival-assurance colonies. Many species are being kept from going extinct in these breeding colonies, but they cannot be released into nature because *Bd* is endemic and persisting on resistant amphibian species. Treating susceptible species with anti-*Bd* bacteria before introduction into the field may allow successful re-introductions. One important open question asks how long bacteria stay on amphibians. Our research with *J. lividum* suggests that it stays on frogs at least 20 weeks[3]. In the future, we may be able to facilitate the re-introduction of amphibians from survival-assurance colonies. Population declines and extinctions due to *Bd* are ongoing and more research is urgently needed into the efficacy of a bioaugmentation strategy for amphibians.

[1]Weldon, C., du Preez, L.H., Hyatt, A.D., *et al.* (2004) Origin of the amphibian chytrid fungus. *Emerging Infectious Diseases* **10,** 2100–2105.

[2]Brucker, R.M., Harris, R.N., Schwantes, C.R., *et al.* (2008) Amphibian chemical defense: antifungal metabolites of the microsymbiont *Janthinobacterium lividum* on the salamander *Plethodon cinereus*. *Journal of Chemical Ecology* **34,** 1422–1429.

[3]Harris, R. N., Brucker, R.M., Walke, J.B., *et al.* (2009 in press) Skin microbes on frogs prevent morbidity and mortality caused by a lethal skin fungus. *ISME Journal*, doi:10.1038/ismej.2009.27.

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Trying to Taming Wild Gingers

Hedychium (heh-DIK-ee-um) or wild ginger species, as they are generally known, were extensively cultivated throughout England and Europe in the nineteenth century where their exotic forms and the heady perfumes of their magnificent blooms made them prized ornamentals in tropical 'hot-houses'. Following the paths of empire builders, a number of species were transported to warmer climates around the world and subsequently three species, *H. gardnerianum* (Kahili ginger), *H. flavescens* (yellow ginger) and *H. coronarium* (white ginger), have escaped cultivation and become naturalized. These now cause significant environmental and economic impact globally, especially in New Zealand and Hawaii (USA) in the Pacific, La Réunion (France) in the Indian Ocean, the Azores (Portugal) in the Atlantic, and Brazil. *Hedychium gardnerianum* has been nominated as among the 'World's 100 Worst Invaders' by the Invasive Species Specialist Group of the World Conservation Union.

Native to the eastern Himalayan range, these coarse perennial herbs are aggressive colonizers of indigenous forest habitats in their introduced range, but display ecological and altitudinal adaptability, persisting under closed rainforest canopies (both littoral and inland) and along forest edges and stream banks as well as in drier sclerophyll and grassland vegetation. Capable of invading pristine and undisturbed forests, their dense growth, tall leafy shoots and extensive rhizomes serve to smother and displace native and sometimes rare and specialized fauna and flora. By preventing recruitment and establishment of native seedlings, they can have a dramatic impact on habitats and ecosystems, degrading native forest communities, compromising regeneration and threatening whole forest viability.

Conventional control methods tend to be labour intensive, effective only in the short term and are often difficult to implement given the inaccessibility of affected sites. Research in La Réunion also showed that comprehensive mechanical control of *H. gardnerianum* could have serious negative knock-on impacts on native biodiversity compared to non-intervention and/or minor disturbance. In Hawaii, monotypic stands are considered lost causes and management programmes are becoming more focused on outlier populations, with efforts shifting towards preservation of pristine and high-value natural areas. Ingress of wild gingers into nature reserves and conservation areas also has implications for the management options available to halt their spread.

Surveys for natural enemies associated with the gingers in parts of their introduced range (Brazil and New Zealand) have failed to identify any suitably specific or damaging candidates. A bioherbicide project based on a wilt-causing bacterium was initiated in Hawaii in the 1990s but has since been abandoned. Classical biological control has long been recommended as the only practical approach for the long-term management of wild gingers in their invasive range.

To this end, the first phase (scoping study) of a biological control programme was initiated by CABI in 2008, funded by a consortium of sponsors from New Zealand and Hawaii (Landcare Research, New Zealand, The Nature Conservancy, Hawaii and the United States Geological Survey – Pacific Island Ecosystems Research Center). As with every new biocontrol initiative, a thorough review of the scientific and botanical literature, as well as records of the target species from UK and subsequently Indian herbaria, gave the expedition geographical focus. A large number of natural enemies is known from economic crops such as edible ginger, turmeric and cardamom, in the same family as wild gingers (Zingiberaceae) and from the literature, and in particular the mycobiota associated with *Hedychium* species suggested potential; no thorough survey had ever been carried out in the native range, however. The wild ginger complex should lend itself well to a biological control programme; there are no other native, representative Zingiberaceae present in Hawaii or New Zealand, it has a narrow habitat preference, a relatively narrow geographical range and the family is vulnerable to pest attack.

A short exploratory survey of Assam, Meghalaya and Sikkim states in the eastern Indian Himalayas was carried by CABI scientists, in collaboration with the Kerala Forest Research Institute, India (KFRI). A wide variety of *Hedychium* species was encountered, including the target species, and all were subject to significant natural enemy pressure. Extensive insect damage to seeds, flower heads, leaves and stems and symptoms of pathogenic infection were observed. Natural populations of the target plants were often found growing in high humidity environments, at forest margins and on steep banks, as inconspicuous members of the native flora and without evidence of invasive behaviour.

As a consequence of the strict implementation of the Government of India's Biological Diversity Act (2002) and the associated Biological Diversity Rules (2004), the export and exchange of biological specimens for taxonomic research from and with India have been restricted. As a result, evaluation of the potential of specimens collected, as well as any detailed identifications have been limited. Given the encouraging variety and impact of insects and pathogens on the target plants, however, further surveys have been recommended to consolidate the catalogue of natural enemies across the seasonal growth cycle and to better assess and prioritize agents for further study. It is hoped that sponsors from New Zealand, Hawaii and other affected counties such as Brazil, the Azores and La Réunion can be solicited to form an international consortium to build on this study and support more comprehensive research.

On a cautionary note, the economic and ornamental appeal of *Hedychium* species in their introduced range cannot be overlooked and opposition from the horticultural industry should be anticipated if a biocontrol agent is ever considered for eventual release. This is particular pertinent for Hawaii, where controversy currently reigns over proposals to introduce a scale to control strawberry guava (*Psidium cattleianum*), despite comprehensive safety testing attesting to its suitability for release. *Hedychium* species are regarded as a cultural resource (e.g. for garlands/lei making) in Hawaii but conflict may be mitigated by prioritizing seed or fruit feeders. Whilst seeds hold no commercial value, they are important vectors in the establishment and spread of *H. gardnerianum*.

This project is still very much in its infancy, but early planning of educational and outreach programmes to address concerns and potential challenges in the Hawaiian community can only be of benefit if biological control is to be accepted as an essential part of the wild ginger management strategy for biodiversity conservation.

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South Africa Resumes Biocontrol Battle against Crofton Weed

Crofton weed, *Ageratina adenophora* (Asteraceae), of Mexican origin, is widely naturalized in many tropical and subtropical areas of the world, invasive in Hawaii, Australia, New Zealand, India and South

Africa, and considered one of the worst weeds in China. Closely related to some of the major weeds in South Africa, *Chromolaena odorata* and *Campuloclinium macrocephalum*, this multi-stemmed, perennial, semi-woody shrub likewise produces hundreds of thousands of wind-dispersed seeds and may become a more important invasive plant. The weed flourishes in wetlands, along stream banks, in forest margins and on cliff faces where it causes loss of water and outcompetes the indigenous vegetation. Members of the Mountain Club of South Africa have been clearing a few valleys in the Magaliesberg range in the Gauteng and North West provinces of South Africa on a regular basis over the last seven years to reduce populations and spread of the weed, but it still remains one of the major weeds in many catchments in that region. The rapid growth and spread of crofton weed, coupled with the ecologically sensitive nature and inaccessibility of many of its habitats, make biocontrol one of the most desirable control options.

In the 1980s, the Plant Protection Research Institute (PPRI) introduced two biocontrol agents, a stem gall fly, *Procecidochares utilis*, and a leaf spot fungus, *Phaeoramularia* sp., into South Africa via Australia and Hawaii. In Australia, they are considered successful in keeping *A. adenophora* under control, but were shown during a recent PhD study by Lisa Buccellato, at the University of the Witwatersrand (WITS), to have a very limited impact in South Africa. Funding from the Department of Water Affairs and Forestry's *Working for Water* Programme and the Agricultural Research Council (ARC) has enabled biocontrol research on this weed to be resumed.

Exploratory surveys were conducted with the assistance of Dr Stefan Neser, ex ARC-PPRI, and colleagues from Universidad Nacional Autónoma de México (UNAM), searching for promising-looking new pathogen and insect natural enemies. The first survey was in August and September 2007. Cultures of a gregarious, leaf-feeding noctuid, *Lophoceramica* sp., and a leaf-mining hispine beetle, probably *Chalepus* sp., were successfully established in quarantine in Pretoria for research into specificity and impact. Other promising insect and pathogen candidates were observed, but collected in too small a number to culture successfully.

Further collection surveys were therefore conducted in October 2008 for pathogens and in February and March 2009 for insects, the last coinciding with flowering of the plants in Mexico to aid in locating them. In total, the surveys yielded many fungal isolates, about 17 Lepidoptera, including stem borers, 14 Coleoptera, including a stem-boring curculionid and a cerambycid, three Diptera, including the previously released stem-galling tephritid and a leaf miner, and about nine Hemiptera. Some are still being reared out to be submitted for identification.

Fungal isolates of various species are being tested for pathogenicity on South African *A. adenophora* plants. The first pustules of the crofton weed rust, *Baeodromus eupatorii,* were developing successfully on plants in quarantine in Stellenbosch in April 2009. Promising insect candidates currently undergoing quarantine evaluation in Pretoria, include the leaf-mining hispine, *Chalepus* sp., a highly destructive, tip- and stem-boring tortricid, and newly collected stem-boring curculionid species. The prospects for the voracious and prolific leaf-feeding lepidopteran, *Lophoceramica* sp., earlier thought to hold a lot of potential, are slightly dampened by its sporadic development on indigenous, related, non-target species. The search is ongoing through surveys in the native home and host-specificity and impact studies in quarantine, to find the most effective and safe candidates to control *A. adenophora*.

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Mist Flower Biocontrol Celebrates Ten Years in New Zealand

An article in the Landcare weeds newsletter[1] highlights the sustained success in New Zealand of biocontrol of a close relative of crofton weed, mist flower (*Ageratina riparia*) ten years after the first agent, the white smut fungus *Entyloma ageratinae*, was introduced. The programme has been exceptionally well monitored and the decline of the weed carefully documented[2,3,4].

As a tenth anniversary 'treat', in November 2008 Jane Barton, who led the project, visited 50 of their 110 sampling plots in the Waitakere Ranges in North Island, west of Auckland. Neither the smut nor the second agent (a gall fly, *Procecidochares alani*) were released in these plots, but they had arrived unassisted. Barton found they are still there in abundance. Mist flower remains under excellent control with ground cover under 0.5% in even the most infested plot (down from a maximum of 36% in 1998). The fungus is maintaining an infection rate of around 55% of plants. Insect galling rates are also being maintained and parasites do not seem to have impacted on the gall fly.

When the programme began in the late 1990s, it was feared that mist flower would spread rapidly into suitable habitats in northern North Island. There is some evidence that spread is still occurring, but slowly, and the weed has vanished from some plots where it was once present. The agents are apparently having no trouble finding the weed when it does turn up in new sites, so while it may remain widespread, it has been rendered impotent and is now just a minor component of the New Zealand flora.

[1]Barton, J, (2009) Still working after all these years. *What's New in Biological Control of Weeds?* No. 47 (February 2009), p. 15.

[2]Barton, J. (2003) When the mist clears, what will we see? *Biocontrol News and Information* **24**, 29N–30N.

[3]Barton, J., Fowler, S.V., Gianotti, A.F., *et al.* (2007) Successful biological control of mist flower (*Ageratina riparia*) in New Zealand: agent establishment, impact and benefits to the native flora. *Biological Control* **40**, 370–385.

[4]Barton, J. (2007) Native flora emerges a winner as mist flower clears. *Biocontrol News and Information* **28**, 29N–30N.

Hopes Brighten for Biocontrol of Weedy Sunflowers in South Africa

South African research on insect natural enemies collected from sunflowers (*Tithonia* spp.) in Mexico indicates potential for biocontrol of weedy species of this genus in South Africa.

The red sunflower, *T. rotundifolia*, and Mexican sunflower, *T. diversifolia*, are native to Mexico, and are currently naturalized throughout the humid and sub-humid tropics in Central and South America, Southeast Asia and tropical and subtropical Africa, including South Africa. Both species are declared weeds (Category 1) in South Africa, with *T. rotundifolia* being particularly invasive in the inland provinces, including Gauteng and the North West Province, while *T. diversifolia* is invasive in the lowveld of Mpumalanga, Limpopo and along the coastal regions of KwaZulu-Natal. They are aggressive colonizers, particularly on disturbed sun-exposed ecosystems with a high water table, including plantations, abandoned sites, and along railways and roads. They are very capable of displacing native vegetation in areas where they occur.

In 2007, the Department of Water Affairs and Forestry's *Working for Water* (WfW) programme provided funding for three years to enable PPRI (the Agricultural Research Council's Plant Protection Research Institute) to conduct research aimed at releasing suitable biological control agents (insects and pathogens) against these invasive sunflower species in South Africa. Nine potential insect biocontrol agents were found on both species of *Tithonia* during field surveys in Mexico in 2007–08, and these were subsequently introduced into South Africa. Five of the nine candidate agents were successfully reared in PPRI quarantine at Rietondale Research Centre.

Most promising so far against red sunflower are two species of leaf feeding chrysomelid beetles, *Zygogramma signatipennis* and *Z. piceicollis*. The two species have very similar life histories and feeding habits. *Zygogramma signatipennis*, initially imported in 2007 by Dr Stefan Neser, is the larger of the two, and is shiny black in colour with silver green markings on the wings. In 2008, *Z. piceicollis* was imported by Dr David Simelane. This has a dark red head and thorax with light grey markings on the wings. Females mostly deposit their eggs singly on the lower leaf surface, but occasionally on flower heads and stem surfaces. Both adults and larvae of the two beetle species feed on the leaves, often skeletonizing them completely, leaving only the leaf veins. Fully grown larvae drop down and burrow into the ground to pupate. Development from egg to adult takes about 5–6 weeks. Although tests are still in progress, preliminary investigations indicate that both species of *Zygogramma* strongly prefer *T. rotundifolia* for feeding and oviposition to other closely-related plant species.

In addition, an as yet unidentified stem-boring weevil was collected from red sunflower in Mexico and introduced into quarantine in South Africa in October 2008. The adults, which are dark grey to black in colour, nibble along the margin of the leaf and lay their eggs in the stems, approximately 4 cm above the ground. The larvae tunnel along the stem, causing a hollow space that is likely to increase the vulnerability of plants to wind damage. Larvae often pupate towards the shoot tip of the plant, from where the adults emerge through an exit hole. A reliable rearing technique is being developed, in preparation for future host-specificity studies on this weevil.

Other species found on Mexican sunflower *T. diversifolia* are also being investigated. An unidentified shoot tip-feeding moth was found on the Mexican sunflower and introduced into quarantine in South Africa in October 2008. Adults, provided with a honey solution as a substitute for nectar, were found to lay their eggs on shoot tips and at the base of the petioles of young leaves. Larvae burrow into the stem tissue and feed internally, gradually causing permanent wilting of the entire branch. Larvae produced by over three pairs of adults can kill an entire plant under laboratory conditions. After preparing exit holes for adult emergence, larvae pupate in the stem. Preliminary investigation, however, has indicated that at least one of the twelve cultivated varieties of sunflower, *Helianthus annuus*, is also attacked by the moth, although the target weed, *T. diversifolia*, remains the preferred host. Intensive host-specificity tests on this moth are still in progress in quarantine.

A defoliating butterfly, tentatively identified as *Chlosyne hippodrome*, was also collected from the Mexican sunflower and introduced into South Africa in October 2007. The adults deposit their eggs in batches under the leaf surface, and these hatch in about five days. The larvae feed on leaves and spin a whitish pupa on any plant surface. A few tests conducted previously indicated that the larvae of the butterfly were able to develop successfully on the target weed only. However, host-specificity tests are still in progress.

Based on the quantity and quality of potential biocontrol agents found on the two invasive sunflowers in their native range, prospects of selecting and releasing suitable biocontrol agents against these alien invaders in South Africa are good.

Source: Mawela, K. & Simelane, D.O. (2008) Optimism prevails in South Africa for biological control of two emerging weeds, red and Mexican sunflowers. *PPRI News* No. 78 (Oct–Dec 2008), pp. 13–15. Newsletter of the Plant Protection Research Institute (PPRI), an institute in the Natural Resources and

Engineering Division of the Agricultural Research Council (ARC) of South Africa.

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Update on Biocontrol of Himalayan Balsam in the UK

Impatiens glandulifera, commonly known as Himalayan balsam, is a highly invasive weed which has spread rapidly throughout the UK since its introduction from its native range, the western Himalayas, in 1839. Originally introduced as an attractive addition to large estate gardens, Himalayan balsam has quite literally exploded out of the confines of the 'garden walls' to colonize wasteland, river banks and damp woodland. When Himalayan balsam grows it has the tendency to form dense monocultures which can outcompete native plant species for space, nutrients and light – thereby decreasing the local biodiversity of the area. As an annual species, Himalayan balsam dies down in the winter leaving the ground bare of supporting vegetation. On river banks this increases the potential for bank and soil erosion. Dead material can also become incorporated into the water body, blocking drainage and thereby increasing the risk of flooding.

Currently, the only options available to control Himalayan balsam are traditional methods such as mechanical and chemical control. In the UK, such control measures are often unsuitable for this species due to the inaccessible habitats in which the plant grows, the need to control the plant on a catchment scale, and the banning of many chemicals for use in and around water under new European Union legislation. Costs are also a concern; current estimates place the eradication of Himalayan balsam from the UK at UK£150–300 million.

Since 2006, funded by the UK Environment Agency, Defra (Department of Environment, Food and Rural Affairs) and the Scottish Government, CABI scientists have been researching the potential to control Himalayan balsam using biological control. To date, four surveys have been conducted throughout the plant's native range (Pakistan and India) at various times throughout the growing season. As a result numerous potential agents having been identified, including both plant pathogens and invertebrates, which now require further testing to determine their host ranges. Observations, coupled with data collected on the size of the plants, show that in the native range Himalayan balsam is a lot smaller than in the introduced range. Herbivory levels are also much higher in the native range, though this is not surprising as few insect species feed on Himalayan balsam in the invasive range, and of those that do, none are consider specialists on Himalayan balsam alone.

Of the agents collected, three stem-boring Coleoptera, namely *Metialma suturella*, *Alcidodes fasciatus* and *Languriophasma cyanea*, show promise as potential biological control agents due to the damage they inflict on the plant in the native range and from field observations of their absence from other *Impatiens* species growing in close proximately to *I. glandulifera*. Adults of all the coleopteran species feed on the leaves of the plants while the larvae develop inside the stem. Plant pathogens also show considerable promise with a *Septoria* leaf spot and a *Puccinia* rust pathogen, which infects the stem and leaves of the plant population, prioritized for host-range testing during 2009.

One of the main components of the research in 2008 was to compile a full test plant list to be used in this and future phases of the project. Second to the identification of potential agents, the compilation of the test plant list is the most important component of a biological control programme and the species on the list need to be carefully chosen in order to scientifically evaluate the host range of the agents being tested. Following the centrifugal phylogenetic method devised by Tony Wapshere in the mid 1970s, and including recent modification suggested by David Briese, a test plant list was compiled containing 68 plant species from 16 families. When choosing which plant species to include in the test plant list, the highest priority species were the most closely related species, in particular native closely related species. In the UK there is only one native *Impatiens* species, *Impatiens noli-tangere*. This is a rather rare species with a scattered occurrence centred around the Lake District area of England and North Wales. In addition there are a further two alien species of *Impatiens* (*I. parviflora* and *I. capensis*) present in the UK and both these have been included in the test plant list.

As the genus *Impatiens* includes rather elegant species with brightly coloured, complex flowers, the genus contains a large number of ornamental species which are grown throughout the UK, in particular *I. walleriana* and *I. hawkeri*, both of which include a number of ornamental varieties and consequently can be found in window boxes and planted on roundabouts throughout the UK. In the test plant list these species are represented by more than one variety to reflect the sheer number of varieties available via garden centres and online seed suppliers. In addition to testing the closely related species, a selection of species has been chosen from the order Ericales, to which *Impatiens* belongs, to widen the spectrum of related plant species tested. Finally, a number of species have been selected as safeguard species and in particular these include species that grow near Himalayan balsam populations in the invasive range.

Since a number of very promising potential agents have been identified the research is now entering the main host-range testing phase. Due to current complications with importing live material from India into quarantine in the UK, much of the research will be conducted in-country in collaboration with the National Bureau of Plant Genetic Resources (NBPGR) in Delhi. Further surveys are planned throughout the growing season of the plant to collect natural enemies, which will then be cultured in Delhi and undergo screening on a selection of test plants from the proposed test plant list.

We would like to express our thanks to our collaborators and colleagues in Pakistan and India for all of their support during this research project, including Dr Ashraf Powell (CABI), Lalit Saini (CABI), Dr K. V. Sankaran (Kerala Forest Research Institute, India) and Dr Y. P. Singh (Forest Research Institute, Dehra Dun, India).

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BLUP Goes the Host Range Estimate

USDA-ARS (US Department of Agriculture – Agricultural Research Service) scientists participating in a biological control programme against Russian thistle or tumbleweed (*Salsola tragus*) have developed an improved method for predicting whether plants related to the target weed could be attacked by a potential fungal biocontrol agent. The method, which they describe in a paper in *Biological Control*[1], has potential for wider use. Undertaking host-range testing of plant pathogens can be labour-intensive, too reliant on narrow datasets, or impractical when numerous or hard-to-grow plant species are involved. The approach developed in this programme also diminishes uncertainty as to whether the reactions of greenhouse-grown plants will reflect those of the species under field conditions.

Russian thistle, an annual plant native to Eurasia, was first introduced into the USA in 1873 by Russian immigrants as a contaminant in flax seed in South Dakota. It was spread further in contaminated seed by threshing crews, in railway (especially livestock) carriages, and by its windblown seed. Today it is common throughout the western USA where it is a problematic invasive weed and a target of biological control efforts.

In late autumn and early winter, Russian thistle becomes conspicuous as it breaks from the soil and is blown across highways and fields – which made it familiar to generations of 'Wild West' film fans. It is a weed of disturbed sites, including roadsides, fencelines, wasteland, poorly tended landscapes, and field and vegetable crops. It reduces yield and quality of many crops, particularly alfalfa and small grains, depletes soil moisture, interferes with tillage operations, and serves as a shelter or food source to many insect and vertebrate pests and crop diseases. It also threatens native plant ecosystems. Plants can accumulate along tree rows and fence lines, posing a fire hazard that requires hours of manual labour to remove, and prairie wildfires are reported to be spread rapidly by ignited balls of burning Russian thistle blowing through grasslands. Water courses are also affected, for example the California aqueduct. It can be a road hazard that obstructs drivers' vision or causes them to swerve to avoid windblown plants. People may also be sensitive to the Russian thistle plant or its pollen.

Many insect biocontrol agents have been imported to try and control Russian thistle over the years, but although insects have become established they have not so far brought about a significant reduction in the weed problem. There are a number of new agents in the pipeline, including an obligate biotrophic rust fungus *Uromyces salsolae*, which was collected from *Salsola* sp. in southwestern Russia.

Initial host-specificity tests with the rust found limited non-target effects on test plants, but the tests were conducted under optimum conditions for disease and it was suspected that they might be reflecting only the response of the germplasm tested. The ARS team developed a new approach that involved integrating plant-disease reaction scores and other data with a matrix made up of DNA sequence information showing the genetic relatedness of the plant species to each other and to the target weed. Analysis using a quantitative genetics (mixed model equation; MME) approach produced best linear unbiased predictors (BLUPs), or the probable susceptibilities, of the different test plants to the weed pathogen. The results indicated that MME analysis was more useful than least squares methods in delimiting the host range of *U. salsolae*. Of the 64 species analysed using MME, only seven non-native *Salsola* spp. showed susceptibility to the fungus, indicating its high specificity and that it should therefore be safe to release for the control of Russian thistle in North America.

The authors say the approach may narrow the list of plants necessary for planning quarantine studies; MMEs were used effectively in this study to generate BLUPs for rare or difficult to grow species that were not actually inoculated and to generate and validate logical lists of non-target plants for host-range testing.

[1]Berner, D.K., Bruckart, W.L., Cavin, C.A. & Michael, J.L. (2009) Mixed model analysis combining disease ratings and DNA sequences to determine host range of *Uromyces salsolae* for biological control of Russian thistle. *Biological Control* **49**(1), 68–76.

Further information/sources: Suszkiw, J. (2009) New approach could improve safety assessments of biocontrol pathogens. ARS News Service.
Web: www.ars.usda.gov/news/

Orloff, S.B., Cudney, D.W., Elmore, C.L. & DiTomaso, J.M. (updated 2008) *Pest notes: Russian thistle*. UC ANR Publication 7486. UC Statewide IPM Program, University of California, USA.
Web:www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7486.html

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Optimizing Flower Species for Biological Control

Scientists from CSIRO Entomology, Australia, and the Lancaster Environment Centre, UK, have investigated how traits of flowers in field margins can enhance biological control in adjacent crops. Many parasitoids and predators that have the potential to regulate pest populations require nectar or other sugar sources to cover their energetic needs. Studies have shown that sugar feeding can increase the lifespan of parasitoids (up to 20-fold), and increase fecundity and their overall activity. These factors have a cumulative impact on parasitism efficacy, underscoring the vital role of food availability in biological pest control.

Non-crop plants are increasingly being used as a tool to sustain biological control. However, the use of non-crop vegetation for the enhancement of natural enemy impact requires a careful selection of non-crop plants. It is increasingly recognized that not all flowers are suited as a parasitoid food source and that flowers may be unattractive or even repellent to the foraging parasitoid. Flower attractiveness is especially relevant for larger parasitoid species whose size enables them to actively locate odour sources or visual targets in flight. Even when the chemistry between flowers and parasitoids is right, this does not warrant a perfect match, as floral architecture or the presence of competitors may prevent parasitoids from physically accessing the nectar.

Using a spatially explicit simulation model Felix Bianchi and Felix Wäckers explored how the attractiveness and accessibility of nectar producing flowers impacts biological control in crops adjacent to flower strips. The model describes the movement, life history and parasitism of a parasitoid in a 40 × 40 m^2 computer landscape and was parameterized for *Cotesia glomerata*. Simulations showed that flower strips with attractive flowers and accessible nectar resulted in the highest longevity, nectar feeding and parasitism levels. Flower strips that were attractive but only had limited nectar accessibility gave rise to higher parasitoid longevity, nectar feeding and parasitism levels than flower strips that were not attractive, but had a high nectar accessibility. This finding suggests that flower attractiveness for natural enemies should be an important criterion for the selection of plant species for flower strips. Attractive flower species should preferably offer accessible nectar, but even if they don't, they can still play an important role in mixed flower margins by attracting predators and parasitoids that may subsequently exploit nectar from less attractive plant species.

The model was also used to investigate whether attraction of parasitoids from the crop to flower strips may result in local natural enemy depletion in the field interior, which may release insect herbivores from control. Although parasitoid migration from the field towards the flower strip occurred in simulations, no local depletion of parasitoids was observed. This finding suggests that enhanced parasitoid longevity by provision of floral nectar sources at the field margin may compensate for the migration of parasitoids to these sites.

The general outcome of this study is that flower strips tailored to the requirements of parasitoids may enhance biological control through the provision of floral food sources. Ground elder (*Aegopodium podagraria*) and oregano (*Origanum vulgare*) are promising candidates to enhance the biological control potential of *C. glomerata* as these plants combine olfactory attractiveness with accessible nectar. Future work will focus on the effect of the spatial arrangement of flowers in and around crops on the biological control potential of parasitoids. In addition, effects of alternative sugar sources in the field, such as honeydew, on the foraging behaviour of cereal aphid parasitoids will be addressed.

Source: Bianchi, F.J.J.A. & Wäckers, F.L. (2008) Effects of flower attractiveness and nectar availability in field margins on biological control by parasitoids. *Biological Control* **46**, 400–408.

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Exotic Ornamental Escapees and Relative Matters

Recent issues of the weed biocontrol newsletter from New Zealand's Landcare Research[1] include articles with a common link. Two garden escapees have been the subject of recent surveys for natural enemies in their home ranges by Landcare Research scientists and overseas collaborators. Both have turned up promising natural enemies and these are currently being prioritized before requests to import them into quarantine are made. A key issue for both projects is not so much non-target effects on native flora, because the targets have no native close relatives in New Zealand, but the potential effects on related introduced, but (at least currently) non-invasive, ornamental species.

Scenting Success

An article in the November 2008 issue ('Adventures in Japan', No. 46, pp.1–2) deals with Japanese honeysuckle (*Lonicera japonica*), a rapacious, rampant climber in New Zealand, but a "well-behaved" plant in its native range in eastern Asia. Three surveys were undertaken to Japan, in collaboration with the National Institute for Agro-Environmental Sciences, Tsukuba, at different times of the year and covering various environmental conditions, from waste habitats to forest and from the coast to subalpine areas. From the natural enemies found, prospects for assembling an array of damaging biocontrol agents look good.

These include a number of lepidopteran natural enemies of this handsome plant, including two equally attractive white admiral butterflies (*Limentis* spp.), one of which (*L. glorifica*) is reported to attack only Japanese honeysuckle. Three moths were also considered particularly promising: *Bhadorocosma lonicerae* has been recorded only from *Lonicera* species on which it destroys stem tips in early spring; stem tips are also the target of a so-far unidentified leaf-tying moth later in the season, while the larvae of the third moth, *Apha aequalis*, consume large amounts of vegetation, which for the investigating scientists added to the appeal of these large, fluffy, "cute" (and non-toxic) caterpillars.

Amongst the many other insect natural enemies found were a longhorn beetle, whose larvae bore the woody stems, and the sawfly *Zaraea lewisii*, whose defoliating larvae specialize on Japanese honeysuckle. Pathogens causing stem or leaf lesions from several well-known genera (*Colletotrichum, Fusarium, Pestiloti, Phomopsis, Phoma*) were collected, as well as plants exhibiting viral symptoms. Attempts to monitor how damaging these were in the field were often thwarted, however, with plants being removed – possibly because they looked untidy – between surveys. Most promising so far is a *Phoma* species associated with herbicide-like dieback at one site.

Permits to import the most promising candidate insect agents into New Zealand have been obtained, with the first shipments due to be made in July this year.

Hedging Thorny Issues

An article in the February 2009 issue ('Can we take the barb out of barberry?', No. 47, p. 3.) tackles an invasive *Berberis*. The thorny but attractive shoots of *Berberis* species make them popular hedging plants, but one species, Darwin's barberry (*B. darwinii*) has escaped and invaded many habitats in New Zealand, from grazed pasture to intact forest, tolerating various soil types as well as frost and drought.

Surveys were conducted in its home range in Chile, in collaboration with scientists from the Servicion Agrícola y Ganadero and the University of Concepcíon. Pathogen surveys produced some 30 fungal taxa. Literature reports of a damaging rust fungus on *Berberis* proved well founded; of some 30 fungi collected on Darwin's barberry, three species including two rusts (*Puccinia berberidis-darwinii* and *P. meyeri-alberti*) appear to merit further study; although the impact of the latter rust is as-yet unknown, the former causes premature defoliation and leaf death. The third fungus, yet to be identified appears the most damaging of the three, causing shoot dieback, premature defoliation, death of braches and potentially whole plants. Insect surveys revealed fewer candidates, but two weevils look worthy of further study: *Berberidicola exaratus* larvae feed on fruit and seeds, and *Anthonomus ornatus* larvae on flower buds – feeding habits of particular interest as the invasiveness of Darwin's barberry is thought to be due, at least partly, to its large reproductive capacity. Host testing is beginning in Chile at the Instituto de Investigaciones Agropecuarias.

Everything (Else) in the Garden

Although there are no close native relatives of either weed to be considered, as Quentin Paynter, contributor to the Japanese honeysuckle article, says, "a key issue remaining to be resolved is what level of attack to other ornamental *Lonicera* species might be acceptable and whether this might compromise or boost the success of the programme." Although some *Lonicera* species are sold as ornamentals in New Zealand, agents that are able to target a range of *Lonicera* species are potentially beneficial because, as well as *L. japonica*, *L. × americana* , *L. periclymenum* and *L. nitida* are all naturalized and apparently in the early stages of invasion in New Zealand. Similarly, although some *Berberis* species are grown and valued as ornamental species, some of them are potentially invasive (based on experience in other countries). That article says that it is possible that biocontrol agents with a wider host range than Darwin's barberry might be preferable – but notes that this is a bridge to be crossed once the host ranges of candidate agents are known.

Sleeping Thistles

Another article in the February 2009 issue ('A shift in thinking', No. 47, pp. 4–5.) tackles the topic of the desirability or otherwise of strict host-specificity criteria for biocontrol agents of alien weeds in a country, such as New Zealand, where some introduced species may have no close relatives among the native flora. The motivation for a study on thistles by Ronny Groenteman (as part of her PhD) was the speed with which exotic species are entering New Zealand (some 25,000 exotic species have been introduced there[2]) and naturalizing (around 2100 species so far[3]). Although relatively few have become invasive to date (about 500 are classified as weeds) and legislation now limits the introduction of new species, the long time lag before invasiveness becomes apparent means there may be many times that number of 'sleeping' weeds already in New Zealand. Should the traditional focus on seeking host-specific biocontrol agents be turned on its head and a multi-targeting strategy be developed in order to prepare for the emergence of these sleepers?

There are over a hundred species of introduced thistles in New Zealand. Only nine are considered economic weeds, although another 38 are known to be weedy in other countries; Groenteman concluded that around two dozen thistles could be invasive 'sleepers'. The system illustrates the conflicts of interest that may be encountered in relaxing rules on host specificity: although there are no native thistles (Cardueae), two crops (globe artichoke and safflower) are related species and another thistle is a potential crop; and there are ornamental thistles to be considered.

A multi-targeting strategy brings its own problems. Non-specific agents tend to have preferred and secondary hosts. It is important to understand how the agents interact, as the ideal suite would control the entire array of target weeds, rather than removing some and leaving gaps for the others to move into. It has been suggested that multi-targeting might work best where there is an overlap between primary (preferred) and secondary host plants, which would allow the agents to build up on the preferred host and spill over onto the less-preferred hosts.

Field experiments and surveys using the weevil *Rhinocyllus conicus* showed that presence of its preferred host, nodding thistle (*Carduus nutans*), was indeed associated with heavier attack on three less-preferred invasive thistle hosts than occurred in its absence. But the heavier level of attack was still insufficient to bring about population declines in the secondary hosts, indicating that a multi-strategy approach might work better for sleeper weeds than for well-established invasives such as the three thistles.

Groenteman concluded that a multi-targeting approach could be exploited but analysis is needed to identify which groups of introduced plants are suitable. A broad analysis of the potential risks of releasing agents with wider host ranges is also needed. The extra effort all this involves might only be justified where a large number of potential sleeper weeds in one group is identified.

[1]*What's New in Biological Control of Weeds?*
Landcare Research – Manaaki Whenua.
Web: www.landcareresearch.co.nz/publications / newsletters/weeds/index.asp

[2]Duncan R.P. & Williams P.A. (2002) Darwin's naturalization hypothesis challenged. *Nature* **417**, 608–609.

[3]Wilton, A.D. & Breitwieser, I. (2000) Composition of the New Zealand seed plant flora. *New Zealand Journal of Botany* **38**(4), 537–549.

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Postharvest Biocontrol: Introspection and Paradigm Shifts

Using microbial antagonists to manage postharvest diseases of fruits and vegetables was an idea that was formulated in the mid 1980s by Wilson and Pusey[1]. Prior to that publication there had been only one report in the literature – of using *Trichoderma* to control *Botrytis* rot of strawberries[2]. Since that time a wealth of research has been conducted and publications have grown from 1–2 per year to over 100 per year and a few commercial products have been released. A recent report by Droby *et al.*[3] has provided an introspective analysis of the past 20 years of postharvest biocontrol research and described future challenges. Early on, these authors established many of the principles that provided the framework for the establishment of numerous research programmes worldwide and in this review they again seek to enumerate the principles and questions that may serve as a guide for the next 20 years.

The original justification for postharvest biocontrol was to reduce or replace the use of synthetic chemicals because of their potential impact on human health, especially children's health, and the environment. The development of resistant strains of postharvest pathogens and the potential loss of registration of some major postharvest fungicides provided additional urgency for the development of alternative strategies. It was reasoned that postharvest biological control had a high probability of success because, unlike field applications, environmental conditions (temperature, humidity, etc.) could be optimized and regulated, and the biocontrol agent could be directly targeted to the desired location of activity. Despite these advantages, the performance of postharvest biocontrol products remains variable and their use remains limited. The use of chemical agents remains the major method of choice for managing postharvest rots. Droby and colleagues voice concern that over the past several years postharvest biocontrol research has seen too much of 'reinventing the wheel' and as a result too little progress has been made towards wider commercial implementation of effective and economically viable biocontrol products. In their review, they outline the basic principles of postharvest biocontrol research, describe the obstacles that have limited its commercial application, and identify areas of research that need to be addressed in order for this approach to reach its full potential.

In terms of the basic principles of postharvest biocontrol, the need for a more complete understanding of the mechanism of action of biocontrol agents is noted. Two critical areas for which rudimentary knowledge exists have to do with the ability of microbial antagonists to adhere to specific surfaces (pathogens, host tissues, and each other) and the ability to undergo fundamental changes in gene expression when cell populations reach a specific level of density (quorum sensing) and/or begin to form biofilms. The literature is rich with the identification of specific genes that regulate attachment, as well as molecules and genes responsible for quorum sensing and biofilm formation. The important role of reactive oxygen species in triggering developmental and environmental responses in yeast has also been reported. However, little of this information has been applied to or investigated in relation to postharvest microbial antagonists. The postharvest biocontrol environment represents a tritrophic interaction between the biocontrol agent, the host, and the pathogen. Understanding these interactions is critical to the development of an effective and reliable postharvest biocontrol product.

An important premise of this review[3] is the need to develop an expanded view of biological control that includes not only the classical view of using one organism to control another but also the use of a biological process, or the product of a biological process. Approaches such the inclusion of chitosan and lysozyme with the biocontrol agent in the formulated product, or the heat pretreatment of a commodity to induce host resistance prior to the application of the microbial antagonists are two examples of this expanded view of biological control. While perhaps rather obvious in its application, it is important to recognize that this expanded definition represents a paradigm shift in the concept of biological control and that this recognition may allow for a fundamental change in the way we think about biological control and the development of biocontrol products and strategies. It is a basic premise that paradigms drive scientific research and have a major impact on how we explore and interpret systems.

Commercial development of postharvest biocontrol products has been rather limited and some products have had very short life spans because of their inability to capture a large enough market, or because of being developed and sold by small companies without a large market presence. However, the largest obstacle to their widespread use has been providing a product that performs effectively and reliably under a wide array of conditions, and also adapts easily to a range of commercial processing systems. The reasons for the variability in performance are not clearly understood and may be due to the presence of pre-established infections, high levels of inoculum, poor storage of the biocontrol product prior to application, or improper application. The impact of mass fermentation and formulation, however, are also factors that may critically impact performance and yet remain largely unexplored in relation to biocontrol products.

Over the past 20 years, biological control of postharvest diseases has grown into a mature field of science and in a relatively short period of time seen successes in commercial application. While such products as Aspire (Ecogen, Inc.) and YieldPlus (Anchor Yeast, Inc.) were short-lived due to inadequate marketing strategies, products like BioSave (Jet Industries, Inc.) and Shemer (AgroGreen, Inc.) are commercially available and new yeast-based products are in development. Considerable effort has been made to integrate the use of postharvest biocontrol products into a production systems approach. The use of preharvest applications as well as postharvest applications, and the incorporation of various additives are two methods that have been used to increase the applicability, effectiveness, and reliability of postharvest biocontrol agents. Interest in the use of microbial antagonists for managing postharvest diseases has greatly increased in developing countries, especially for exotic, tropical fruits grown mainly for local consumption, because of the ability to easily identify local strains of microbial antagonists. As discussed in the review by Droby *et al.*[3], the use of biocontrol agents as an alternative to the synthetic, chemical fungicides has many constraints and obstacles. The advances made and commercial products thus far developed, although limited, represent promising possibilities. A probable scenario is that the use of postharvest biocontrol as a management approach will continue to grow at a slow rate, especially when used in combination with other alternative approaches. The original premise made back in the 1980s that the potential success of postharvest biocontrol is great because of being able to control the environment, and target the biocontrol agent still holds. As critical questions regarding the mechanism of action and the science of fermentation are answered over the next 10–20 years, it is expected that the use of postharvest biocontrol products will increase and become more commonplace.

[1]Wilson, C.L. & Pusey, P.L. (1985) Potential for biological control of postharvest plant diseases. *Plant Disease* **69**, 375–378.

[2]Tronsmo, A. & Dennis, C. (1977) The use of *Trichoderma* species to control strawberry fruit rots. *Netherlands Journal of Plant Pathology* **83**, 449–455.

[3]Droby, S., Wisniewski, M., Macarisin, D. & Wilson, C.L. (2009) Twenty years of postharvest biocontrol research: Is it time for a new paradigm? *Postharvest Biology and Technology* **52**, 137–145.

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Fish in Waiting for Malarial Mosquitoes in Tanzania

Scientists at the Tropical Pesticide Research Institute (TPRI) of Tanzania's Ministry of Agriculture and Food Security and the US-based Poseidon Science Foundation are collaborating to develop a method for using larvae-eating fish to control malarial mosquitoes in seasonal water bodies.

The concept of using larvivorous fish as biological control agents is an old one, with some past successes. However, the introduction of the mosquitofish, *Gambusia affinis*, in new habitats has been known to devastate indigenous freshwater organisms. Although local species of fish have been studied extensively as a means of larval control with notable success in India and parts of Africa, their effectiveness has been limited to permanent bodies of freshwater.

Malarial mosquitoes are generally found in higher elevations in temporary pools that dry up seasonally, thus preventing long-term control by larvivorous fishes or even chemical control agents. When the water dries up, the fish die while the mosquitoes enter a dormant state until the next rains, when the pools fill again. Moreover, these malarial areas are generally inaccessible making vector control expensive and sporadic at best.

The chances of finding a fish that could work as a mosquito biocontrol agent in these circumstances might seem remote: it would need to be able to maintain permanent populations in temporary habitats; the population must be present when the seasonal rains start and capable of preying on mosquito larvae as the hibernating eggs begin to hatch. Yet such fish do exist, and a candidate species from Tanzania, the annual fish *Nothobranchius guentheri*, is the subject of the new initiative.

Annual fish, which are endemic to Africa and South America, are a unique class of fishes that survive in alternating dry and wet seasonal pools by entering a state of diapause (like the mosquitoes). The adults are decimated when the water dries up, but the embryos, buried in the substrate during the previous breeding season, go through various phases of suspended animation to survive drought. With the onset of the next rainy season, these embryos hatch to feed on mosquito larvae that hatch around the same time. The fish can survive in pools as small as depressions made by elephants' feet.

The most extensively studied annual fish are in the genus *Nothobranchius* which occupy a wide range of habitats in Africa. *Nothobranchius guentheri* is considered ideal for a malaria vector control programme because, as well as surviving in temporary pools of freshwater, its small size allows it to seek prey in between leaves and grass in shallow areas, and also makes it less suitable to be harvested as a food source by the local human population. Also, the species does not survive in permanent bodies of freshwater and thus poses no threat to other indigenous fishes that inhabit them.

Scientists from the Poseidon Science Foundation have been working on developing mass production/ long-term storage of the embryos in suspended animation and convenient methods of disseminating the embryos for eventual use in vector control. Moreover, three decades of research at Poseidon and by other biologists working in this field have provided increased understanding of the life cycle of annual fishes.

Poseidon's collaboration with TPRI represents the most recent attempt to use these fishes for biological control. The project involves studies on methods of field introduction and monitoring of larvivorous activity in controlled test ponds. Field introductions will follow once the ecological, conservation and efficacy studies have been successfully undertaken. Eventually, it is hoped this effort will expand into mass production of the fishes locally and their dissemination to areas of Tanzania where malaria is endemic.

If successful the method is expected to complement other anti-malaria approaches such as pesticide use including insecticide-treated mosquito nets, and artemisinin drugs.

Sources: Mkoka, C. (2009) Larvae-eating fish employed in malaria fight. *SciDev.Net* 16 Apr 2009. Web: www.scidev.net

Poseidon Science Foundation.
Web: www.poseidonsciences.com

Recent Developments in Agricultural Entomology Research at Rhodes University

South Africa's Eastern Cape has a number of different floristic biomes that ensures a wide diversity of agricultural ecosystems. The Department of Zoology and Entomology at Rhodes University is ideally placed to research pest control problems experienced in this area. Indeed entomology almost has an obligation to address these problems. The department has been involved in agricultural projects since its inception in 1905 when the first head of department, Professor Duerden, worked in wool and ostrich feather quality. In the 1970s considerable work was undertaken in the control of citrus pests.

In the last seven or eight years there has been a rejuvenation of agricultural entomological research in the department and projects have been undertaken on the control of pests in cabbages, chicory, peppers, olives, macadamias, litchis, potatoes and citrus. More recently the main focus has been the control of citrus pests using microbes such as fungi and viruses. These projects have focussed not only on commercial farming systems, but also on sustainable rural livelihoods. The philosophy of this work is:

- To research problems driven by industry
- Commitment to undertaking fundamental science on applied systems
- Commitment to IPM

It is widely accepted that pests should be controlled using less insecticides and more through natural enemies such as spiders and wasp parasitoids.

It is hoped that this research focus will attract more students to Rhodes University as they can see the applied significance of undertaking a degree in entomology.

Waainek Research Laboratory

Space is limited on the Rhodes University campus and space had to be sought to house students and researchers involved in undertaking projects on the control of agricultural pests. The laboratory that was opened on 12 March 2009 used to house the Tick Research Unit at Rhodes. The unit closed down in 1993 and the buildings have been largely unused since that time. In late 2008 Rhodes University made some funds available to the Discipline of Entomology to renovate the Waainek Research Laboratory. With very little funding this laboratory is now fully functional and houses a research officer, a PhD student, two masters students and an honours students, with more students to follow. The opening was attended by several people from the agricultural industry, academics and students.

Funding

To date this research group has received funding from: Chicory SA Ltd, Citrus Research International, Citrus Academy, River Bioscience, Insect Science (Pty) Ltd, Litchi Growers Association, Southern Africa Macadamia Growers Association, Carara Agro Processing Services, Rhodes University Joint Research Council and Rhodes University.

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IPM Systems

This section covers integrated pest management (IPM) including biological control and biopesticides, and techniques that are compatible with the use of biological control or minimize negative impact on natural enemies.

Armyworm NPV for Africa: Illustrating Problems of Promoting Biopesticides in Africa

The recent outbreak of 'armyworms' in the West African state of Liberia highlights the difficulty of controlling crop pests in sub-Saharan Africa, particularly the major irruptive and migratory insect pests. It also begs the question of why biological control agents (BCAs) have not been developed and adopted for the management of these pests in Africa. Previous reports have identified some issues that have impeded BCA development in the continent[1]. Here, we review the progress with developing one of the more promising BCAs, the *Spodoptera exempta* nucleopolyhedrovirus (SpexNPV), with a view to illustrating some of these issues and perhaps throwing new light onto the ways in which BCA adoption might be promoted in Africa.

A major issue is the availability of suitable BCAs. Many pests in Africa, particularly endemics like the Liberian 'armyworm', *Achaea catocaloides*, are so little studied that, for many, we have not yet identified any potential BCA that could be developed as an effective control agent. In the case of the much more widespread and devastating African armyworm, *Spodoptera exempta*, research has already identified SpexNPV as an effective BCA[2]. It has several advantages over other potential BCAs, including the fact that it is a member of a well-understood group of pathogens (the baculoviruses), that are of assured safety, and are already widely used for pest control in Europe, North America and Asia.

The limited host range of many BCAs limits their use. This is seen as a particular constraint in African farming because multiple pest threats are common, and the use of a single broad-spectrum control for different classes of pests is the norm. In the case of African armyworm, the outbreaks comprise a single pest species and SpexNPV is the main endemic pathogen. There are many different strains of SpexNPV, and the strategic use of these strains in the biological control of armyworms is currently under active investigation.

The slower speed of kill of most BCAs remains an issue. Often BCA action is too slow for responsive spraying to be effective. For example, trials have shown that when sprayed on young caterpillars, SpexNPV kills within 3–4 days, compared with just a few minutes for conventional chemical insecticides. This means that application needs to be timed early in the pest outbreak if it is to be effective, and this requires a good early-warning system. Unusually, an effective forecasting network does exist for African armyworm in Tanzania, comprising a national network of pheromone traps to warn of migrating armyworm moths, as well as scouting teams and a growing network of community-based forecasters. Unfortunately, there are no comparable systems in place in most countries neighbouring Tanzania.

BCAs also have low persistence relative to most synthetic insecticides. This is important when spraying cannot be easily synchronized with pest arrival on the crop, and prophylactic action is required. This is not such an issue with armyworms, as outbreaks are controlled by spraying larvae whilst they feed on the crop, and NPV is very quickly ingested by feeding larvae (probably within an hour). Of course, if infection by BCAs can be established early in the pest cycle, then 'secondary cycling' by such self-replicating BCAs as fungi, nematodes and viruses can mean that BCA persistence is much better than that of chemical insecticides, which can only degrade over time. If IPM and scouting were practised more in Africa, the issues of host range, speed of kill and persistence would be less of a constraint. However, despite IPM being national policy in many African countries, a lack of resources and skills prevents any widespread use of IPM in practice outside the high-value commercial sector.

Storage of BCAs can be a problem as most BCAs have a limited shelf-life at ambient temperatures compared to that of chemicals, which typically last in excess of two years. These BCAs need cool-chain conditions for long-term storage and this is certainly not available in rural Africa, and is often a problem even in the cities. To surmount this obstacle, SpexNPV is adapting a powder formulation system developed in Brazil by EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária – Brazilian Agricultural Research Corporation) as a low-cost formulation with good shelf-life.

Supply is a real issue for BCAs in Africa. This is because African markets for BCAs are small outside horticultural hotspots such as South Africa and Kenya, discouraging local production of BCAs by commercial industry. There is now a nascent BCA industry starting up in Kenya, and a well-established one in South Africa producing biopesticides (including Green Muscle®, see below) and baculovirus insecticides. However, elsewhere in sub-Saharan Africa there is no commercial production of BCAs. Importation by these countries would be an option if registration processes for BCAs were more transparent, suitably costed and reliable. However, despite some harmonization of BCA registration regulations, it still remains relatively uncertain and expensive to register BCAs in many parts of Africa. This will probably be an issue for SpexNPV in Tanzania, but efforts are in hand to reform the registration process and align it with Kenya, where a working system is well established.

The cost of BCAs produced outside Africa is generally high in comparison to the chemical insecticides African farmers are familiar with. This should favour the kind of local low-tech production of BCAs that has flourished in Brazil, India, China and Thailand. For SpexNPV the plans is to mass produce it through field-based production in Tanzania[3] which would mean a cost (of around US$ 3/ha) that is lower than the price of chemical pesticides (around US$ 10/ha)[3].

Institutional models to promote BCA adoption in Africa are a problem. There has been little progress in getting BCAs to generate impact, other than with the classical introductions to control exotic pests, such as the cassava mealybug (*Phenacoccus manihoti*) control programme. The simple commercial route is relatively expensive. For example, the use of *Bt* (*Bacillus thuringiensis*-based) insecticides is mainly restricted to commercial horticulture, where resistance has made the use of cheaper chemical alternatives untenable. The development of endemic BCAs, through a commercial R&D route, such as the baculovirus product Cryptogran™ for false codling moth (*Cryptophlebia leucotreta*) control in South Africa, shows that commercial R&D can work, but probably only for high-value horticulture in places such as South Africa and Kenya.

Public–private partnerships (PPPs) may provide a sustainable mechanism for local production. The use of such PPPs for the development of BCAs seems much more appropriate for Africa than the traditional commercial routes. A prime example of this was the LUBILOSA project, which developed the Green Muscle® fungal insecticide for locust and grasshopper control using public sector aid funding and public sector technology development, but eventually transferred production to the private sector. This sort of approach is especially appropriate for migratory and trans-boundary pests, like locusts and armyworms, where many countries are potential targets and hence beneficiaries.

BCAs offer novel ways to manage pests. They exploit the interaction between pests and their natural enemies. These interactions are infinitely more subtle and complex than those between insects and chemicals. This is part of the reason why resistance to chemical insecticides is such a problem in the management of crop pests. BCAs offer novel opportunities for exploiting these interactions. For example, 'secondary cycling' of entomopathogenic fungi has proved to be an effective medium-term strategy for the control of grasshoppers. Many microbial BCAs cause sub-lethal effects in their surviving hosts, which may reduce the impact of pest species even when applied at low dosages. Many also are transmitted between generations via vertical transmission, offering potential routes for the widespread dissemination of BCAs. All of these mechanisms are currently being explored in the armyworm–SpexNPV system, with a view to long-term strategic control of armyworm in eastern Africa.

SpexNPV is a very promising candidate to be the next BCA for development. This is because it has proven to be highly effective in field trials[2] and has a real product niche. However, progress is constrained by the absence of funding to bridge the gap between basic research and its applied use. The research councils will generally not fund this sort of applied research. Although development agencies do fund some research, they are often hesitant to support the applied R&D needed to turn research into practice, which can be a long process. This is especially true in Africa, where logistics can be more demanding and progress slower, and also for migratory pests, for which it can be difficult to locate pest outbreaks early enough to be able to conduct properly controlled and resourced trials. SpexNPV development has continued for more than a decade, despite intermittent gaps in funding. However, it has proved difficult to secure the funding required to mass produce SpexNPV, and it seems likely that it will take outbreaks on the scale of those seen in Liberia to trigger potential donors into action.

In conclusion, there are still many factors constraining the use of BCAs in Africa. Some of these are issues that can be easily addressed via good scientific research, but others relate to the whole context of African agriculture and may not be resolvable in the short term. However, with appropriate technologies, political goodwill and sufficient funding, there are some BCAs that could play a significant role in meeting the pest threats to African food production and poverty.

For further information about the African armyworm and its biological control, visit: www.lancs.ac.uk/staff/wilsonk4/ARMYWEB/ARMYWEB.html

[1]Cherry, A.J. & Gwynn, R.L., (2007). Perspective on the development of biocontrol in Africa. *Biocontrol Science and Technology* **17**, 665–666.

[2]Grzywacz, D., Mushobozi, W.L., Parnell, M., *et al.* (2008) Evaluation of *Spodoptera exempta* nucleopolyhedrovirus (SpexNPV) for the field control of African armyworm (*Spodoptera exempta*) in Tanzania. *Crop Protection* **27**, 17–24.

[3]Mushobozi, W.L., Grzywacz, D., Musebe, R., *et al.* (2005) New approaches to improve the livelihoods of poor farmers and pastoralists in Tanzania through monitoring and control of African armyworm, *Spodoptera exempta*. *Aspects of Applied Biology* **75**, 37–45.

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IPM for Flies in Feedlots

A report from Australia by Queensland Department of Primary Industries and Fisheries (DPI&F) scientists describes the development of an integrated management strategy that reduces nuisance fly populations (principally house flies, *Musca domestica,* and stable flies, *Stomoxys calcitrans*) in cattle feedlots (confined animal rearing areas) in southeast Queensland[1]. Components of the strategy include augmentative releases of parasitoids and fungal biopesticide applications. The three-year project was conducted in collaboration with a scientist from USDA-ARS (US Department of Agriculture – Agricultural Research Service) and funded by Meat & Livestock Australia (MLA) and the Queensland Government.

Despite efforts by the feedlot industry to improve manure management in recent years, the flies that breed in it remain a problem in cattle rearing facilities. The project included research and development of existing and new tools:

- Removing manure from the entire pen proved unnecessary but the frequency with which it was cleared from where uncompacted manure tends to accumulate, along fence lines, was. Removing it monthly, fortnightly and weekly decreased numbers of fly pupae 55%, 67% and 84% compared with a three-monthly cleaning interval.

- Insecticides were effective in only some situations. The larvicide cyromazine applied under fence lines reduced immature and mature flies but only when applied after the fence lines had been recently cleared of manure; importantly it did not reduce fly parasitism rates. Adulticides had less effect: spraying cyfluthrin on feedlot structures gave a small, transient reduction in stable fly populations but had no apparent effect on house flies.

- Augmentative releases of mass-reared parasitoids, *Spalangia endius*, contributed to fly control. *Spalangia endius* is common in Australian feedlots and is also one of several species used against manure-breeding flies in the USA. Results from various field and feedlot trials in southeast Queensland indicated that fewer flies emerged where parasitoids had been released, a trend of increasing *S. endius* populations and a greater percentage of this species in the parasitoid community.

- Fungal biopesticides were shown to have potential, with *Metarhizium anisopliae* and *Beauveria bassiana* shown to selectively infect and kill the flies. Isolates chosen for efficacy and high spore production in culture were bioassayed against house flies for a range of properties: spore uptake from sprayed surfaces and food, efficacy of spray and bait formulations, lethal spore levels, and the effect of combining fungal species. Feedlot trials using formulated *Metarhizium* spores gave promising results in terms of much higher fly mortality than in untreated areas and the fungus was re-isolated from flies netted after spraying. Moreover, mortality remained higher than pre-spray levels and *Metarhizium* could still be isolated from flies netted a week after spraying (although at lower levels).

A significant feature of this project was the collaboration between researchers and the commercial sector in carrying out the above research and developing the practical integrated management strategy. Bugs for Bugs, a company producing a wide range of biological control agents based in Mundubbera, Queensland, characterized the wasps and developed mass-rearing techniques and a quality control assurance programme. *Spalangia endius* is now available from the company as a biocontrol tool. To be successful, releases should begin before fly populations increase and continue throughout the expected fly season at the recommended rates.

Becker Underwood Australia, the sole commercial producer of fungal biopesticides in Australia at present, produced *M. anisopliae* spores for the trials. The report recommends further development of the *M. anisopliae* based biopesticides to a commercial fly control product. It notes that this will need to be registered with the Australian Pesticides and Veterinary Medicines Authority, for which additional efficacy data will be needed, and recommends that commercialization should be pursued by DPI&F, MLA and Becker Underwood.

In 2007/2008, trials in two locations, in the Brisbane Valley and Warwick Shire, allowed conventional practices to be compared with the new IPM strategy, which comprised frequent fence line clearing, augmentative parasitoid releases, spraying fungal biopesticides, and focused use of insecticidal fly baits. Adult house fly and stable fly populations were reduced 36% and 40%, respectively, by the IPM strategy, and increases in fly parasitism rates, fungal infections and mortality were recorded.

An integrated fly management package for nuisance flies in cattle feedlots is now being produced, incorporating ecological knowledge about the major fly pests and their natural enemies and the effects of flies on feedlot operations into the results of this project. The report's authors also recommend the expansion of the use of parasitoids and fungal biopesticides to other industries in Australia with similar fly problems.

[1]Urech, R., Leemon, D., Green, P., *et al.* (2008) Integrated management of nuisance fly populations on cattle feedlots. Final Report, Project B.FLT.0326. Meat & Livestock Australia Ltd.

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Killing Old Mosquitoes for Sustainable Malaria Control

Although malaria is the world's greatest killer amongst vector-borne human diseases, most malaria parasites (*Plasmodium* spp.) do not survive in a mosquito long enough to infect anyone. The apparent paradox arises because adult malarial mosquitoes suffer such high mortality that most mosquitoes do not live long enough for any *Plasmodium* parasites they acquire in their first blood meals to develop the infectious stages passed back to humans. According to a recent paper in *PLoS Biology*[1], this provides a window of opportunity for a novel approach that would be almost immune to the development of insecticide resistance – and one that biopesticides are pre-adapted for. The authors argue that targeting older mosquitoes is essential if we are to achieve a sustained reduction in malaria worldwide.

Although some control initiatives target larvae in breeding sites (e.g. using *Bti*: *Bacillus thuringiensis* var. *israelensis*), controlling adult mosquitoes is the most effective way of reducing vector populations, and thus incidence of malaria. Such strategies target female mosquitoes where they rest or feed. Indoor residual spraying is the basis of control, but in recent years campaigns to make bed nets, particularly long-lasting insecticide impregnated nets, widely available have been credited with massive reductions in malaria in some countries according to the latest WHO (World Health Organization) report[2]. These strategies rely on synthetic insecticides like DDT and pyrethroids, and history shows that they carry a high risk of becoming ineffective because the high insecticide coverage and rapid insecticide-induced mortality they require drive the evolution of insecticide resistance in mosquito populations. Resistance management (e.g. alternating insecticides) can delay but not prevent this happening. Moreover, current restrictions on insecticide use leave almost no options for resistance management of insecticides used in impregnated bed nets.

In their *PLoS Biology* paper, Read *et al.* describe how they investigated whether differences in the lengths of the reproductive cycles of the mosquito host and the malarial parasite provide opportunities for disease control.

- A blood meal is necessary for female mosquitoes to reproduce, because blood proteins are needed for the eggs to mature; once mature, the eggs are laid before the mosquito seeks another blood meal, which starts another egg maturation and laying (gonadotrophic) cycle. A single cycle takes 2–4 days.
- Malarial parasites taken in with a blood meal undergo a complex reproduction and development process, which ends with mature offspring migrating to the salivary glands from where they are injected into a new host when the mosquito takes its next blood meal. The time from a mosquito ingesting a *Plasmodium*-infected blood meal to becoming infective is about 10–14 days, or 2–6 gonadotrophic cycles.

A high natural adult mortality rate means that most female mosquitoes go through only a few cycles before dying, and the long development time of the *Plasmodium* pathogen means that most of the eggs a mosquito lays during its lifetime will be laid before it becomes infective – and the majority do not live that long.

Read *et al.* report how they used data on mosquito lifespan and malaria development from four foci of intense malaria transmission (two in Nigeria; one each in Tanzania and Papua New Guinea) in a feeding cycle model. They found that an insecticide-based strategy targeting mosquitoes *after* they had gone through four gonadotrophic cycles but *before* they became infective was able to reduce infectious bites by 95%. Then, using fecundity data generated in the above model in a population genetics model, they were able to predict that resistance to late-acting insecticides would spread slowly, if at all, because there was less selection pressure from insecticide-induced mortality after peak reproduction was passed. While current insecticide programmes show a 99.8% reduction in the number of infectious bites, there is enormous selection for resistance precisely because of this high and indiscriminate mortality, which includes reproducing females. In Read *et al*'s model, conventional insecticide use reduced a mosquito's lifetime reproductive success by 85%, while late-acting insecticides reduced it by only 22%.

Resistance to conventional insecticides used in malaria control has been reported to carry substantial costs (and these can be exploited in resistance management based on alternating insecticides) but they are easily outweighed by the enormous benefits of resistance. This would not necessarily be the case for late-acting insecticides, however. Read *et al.* discuss what properties would make them least prone to the development of resistance in target populations. They argue that, as well as being effective against older mosquitoes, a late-acting insecticide would ideally be more effective against malaria-infected mosquitoes, and resistance to it would carry lifetime fitness costs.

The authors say they "are unaware of any attempts to evaluate potential insecticides for these properties." They discuss how targeting older mosquitoes might be achieved in practice through adapting application practices for existing insecticides (for example, exposing mosquitoes to cumulative sublethal doses, developing microencapsulated formulations) or by developing novel chemicals that target older or infected mosquitoes. However, as older mosquitoes are known to be more susceptible to some insecticides, and malaria parasites impose considerable metabolic costs on their host, they underline the importance of investigating whether lower insecticide doses than those currently applied could specifically target older and infected mosquitoes. Read *et al.* say "the aim here is disease control, not necessarily insect control". In fact, they add, killing mosquitoes may not be necessary if they can be prevented from transmitting malaria by another means. They suggest host-location, host-feeding and flight behaviour could be useful areas for research.

Although the paper initially discusses the prospects for adapting the use of synthetic products to kill older mosquitoes or prevent them from transmitting malaria, Read *et al.* go on to argue that bioinsecticides already do this. They point out that their slow mode of action, which traditionally puts them at a disadvantage to synthetic insecticides in spray programmes that aim for fast knock-down, becomes an advantage in this situation. Other research on two entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*) that infect mosquitoes showed that they cause death 7–14 days post-treatment and have a disproportionate impact on malaria-infected mosquitoes. Field trials showed how entomopathogens could be sprayed onto walls or bed nets to infect mosquitoes that come into contact (see *BNI* 26(3), 79N–81N (September 2005), 'Malaria biocontrol grows up' and refs therein). Read *et al.* say that other prospective biocontrol agents, such as *Wolbachia* and densoviruses, also kill mosquitoes late in life.

In more general terms, what is now needed, according to the authors, is a re-assessment of the criteria for evaluating insecticides for malaria control – not least because current the WHO Pest Evaluation Scheme (lab test) criteria for insecticides for both indoor spraying and impregnating bed nets requires 80% mortality up to 24 hours post-treatment in young adult females; just the population subset that, according to Read *et al.*, should *not* be targeted and whose elimination imposes greatest selection for resistance. Ironically, the success of the Global Malaria Action Plan in promoting spraying and bed net dissemination will impose unprecedented selection for resistance. While this may bring about an urgently needed fall in malaria cases worldwide, a move to late-acting insecticides could provide a means for sustaining this when, as is inevitable, mosquitoes develop resistance to the insecticides currently being used.

[1]Read, A.F., Lynch, P.A. & Thomas, M.B. (2009) How to make evolution-proof insecticides for malaria control. *PLoS Biology* **7**(3), e1000058.

[2]WHO (2008) *WHO malaria report 2008* Web: www.who.int/malaria/wmr2008

Larvicides Could Stage Comeback for Malaria Control in Africa

Two studies in East Africa, one in urban Dar es Salaam in Tanzania[1] and the other in the rural highlands of western Kenya[2], may revive interest in the potential for larvicides to contribute to control of malarial mosquitoes and disease transmission in Africa. The authors of the Tanzanian study say that the approach, which was favoured in the first half of the twentieth century, may be able to complement current approaches that use indoor residual spraying and insecticide-treated bed nets (ITNs) to target adult mosquitoes, although they expect these to remain the mainstay of anti-malaria initiatives.

Larvicides' fall from favour came with the advent of DDT, which controlled adult mosquitoes and was thought a more effective way of reducing populations, but was also related to growing health and environmental concerns about spraying synthetic insecticides on water bodies where mosquito immature stages live. The safety aspect was overcome with the development of the bacterial biopesticide *Bacillus thuringiensis* var. *israelensis* (*Bti*) which is active against the larvae of the *Anopheles* malaria vectors. This has been widely deployed across the northern hemisphere, but its introduction to Africa has been hampered by concerns about cost and sustainability.

Geissbühler *et al.*[1] undertook the study in Dar es Salaam to investigate what impact larvicides could have in an urban environment, acknowledging that malaria in rural areas is considered to be the main problem (and where most research has been conducted), but with the knowledge that the African urban population is growing and expected to be more than 50% of the total population by 2030. They conducted the pilot study under the auspices of the Dar es Salaam City Council Urban Malaria Control Programme (UMCP) in three wards of the city, a total area of 17 km^2 with 128,000 inhabitants. UMCO was established in 2003 and had spent three years developing new, sustainable and affordable systems for applying microbial larvicides by mobilizing a community-based team of operators.

Tanzania has emphasized the widespread use of ITNs as its highest priority for controlling malaria but, although the World Health Organization has reported some outstanding successes where a combination indoor residual spraying and ITN use has dramatically reduced the incidence of malaria[3], malarial mosquitoes have recently been observed to feed outdoors in urban areas more than they do in rural areas and, especially in the case of the primary vector *An. gambiae*, to feed early in the evening before people retreat indoors. Indoor residual spraying and ITNs, in particular, rely for efficacy on night-feeding behaviour in malaria mosquitoes.

In Dar es Salaam, the 300-strong community-based team applied *Bti* weekly for a year to open habitats where *Anopheles* malarial vectors were likely to breed. A comprehensive survey of every potential breeding site was also conducted weekly, and the impact of treatment on mosquito populations and malaria transmission was recorded. Despite what they describe as sub-optimal application of *Bti*, researchers recorded a reduction in malaria transmission in treated areas, with a 72% reduction in the prevalence of malaria infection among young children. They found that *Bti* treatment provided protection at least equal to that provided by an insecticide-treated net, and at a similar cost (US$1/person/year compared with an average of $2/year for a net, which is often used by more than one person).

On the face of it this might be puzzling as, although *Bti* suppressed *Anopheles* populations by 32% on average over the year, it suppressed the secondary vectors *An. funestus* and *An. coustani* substantially and had no overall significant effect on the primary malaria vector *An. gambiae.* However, *An. gambiae* was most effectively reduced during drier periods while control during the annual rains was poor (owing to cash flow restrictions at the outset and the difficulty of treating many transient and inaccessible habitats). Moreover, although *An. gambiae* populations peaked during the rainy season, the most sporozoite-containing (malaria-infected) *An. gambiae* were caught during the drier months that followed when warmer conditions favoured parasite development and mosquito survival – and this was also when most malaria transmission was recorded. The authors point out that the study was uncontrolled, and other factors may be involved in the fall in disease transmission – for example, people may have modified the measures taken against malaria during the study period – but they argue that there is a case for re-assessing larvicides, particularly given the limitations to ITN efficacy found in this urban situation.

Geissbühler *et al.* draw parallels between their findings and those in the as-yet unpublished study in the densely populated rural highlands of western Kenya[2], which has also shown the effectiveness of using larvicide application in combination with ITNs as a malaria prevention strategy, but say that while the two studies indicate a useful role for *Bti* in anti-malaria strategies, many questions need to be answered first and further research and trials are needed. Above all, they stress that they see larvicidal and adulticidal approaches as complementary in tackling malaria in Africa.

The programme in Dar es Salaam has already been extended to protect over 600,000 people, with lessons learned during this pilot study being translated into major improvements in the delivery system to reduce costs and improve performance. Furthermore, expansion to cover the entire city was considered at the stakeholders' meeting of the US President's Malaria Initiative held in Tanzania in April 2008 and the National Malaria Control Programme has set itself the target of setting up such programmes in five cities by 2013.

The study was supported by the Bill & Melinda Gates Foundation, Valent Biosciences Corporation, Research Triangle International, the US President's Malaria Initiative and the Wellcome Trust.

[1]Geissbühler, Y., Kannady, K., Chaki, P.P., *et al.* (2009) Microbial larvicide application by a large-scale, community-based program reduces malaria infection prevalence in urban Dar es Salaam, Tanzania. *PLoS ONE* 4(3): e5107. doi:10.1371/journal.pone.0005107.

[2]Fillinger, U., Ndegwa, B., Githeko, A. & Lindsay, S.W. (in press) Integrated malaria vector control with microbial larvicides and insecticide treated nets in the western Kenyan highlands: a controlled trial. *Bulletin of the World Health Organization.*

[3]*World malaria report, 2008.* WHO.
Web: www.who.int/malaria/

Training News

In this section we welcome all your experiences either from working directly with the end-users of arthropod and microbial biocontrol agents, or from other relevant educational activities on natural enemies and IPM aimed at students, farmers, extension staff or policymakers.

How to Collaborate with Farmers on IPM Research*

In recent years, IPM extension came to mean FFS (farmer field school). Field schools meet weekly to observe and discuss pests in the field, over a whole growing cycle.

There has now been time for detailed evaluations of FFS. The results consistently show that farmers like FFS and change their attitudes as a result of it. FFS graduates learn about pest ecology, and tend to decrease their insecticide use. Some studies show that FFS graduates save on production costs or harvest more, although all of the studies do not replicate these results. Some quantitative studies of FFS suggest that there is actually little overall impact of FFS programmes.

FFS graduates do not teach what they have learned to their neighbours, which limits the cost-effectiveness of FFS. Field school experts are now arguing that field schools "are not meant for technology transfer" and there is a need to experiment with how to combine FFS with mass media, extension, etc.

FFS may be better suited to stimulating collaborative research with farmers than for extension itself. FFS gives scientists a chance to see how farmers react to scientific ideas and, because the FFS permits farmers to understand the reasons behind a new technology, to suggest improvements.

For example, farmers in Central America improved traps to catch slugs (molluscs) during FFS. Farmers in Indonesia created ploughing practices to kill stem borers, and there are many other examples. CIP (International Potato Centre) researchers in Peru have adapted FFS for research. In one experience researchers organized FFS graduates into CIALs (local agricultural research committees) to do formal, on-farm trials of rotation crops to decrease soil-borne bacteria, besides inventing several ways of controlling bacterial wilt in potato.

There are many extension methods available, although their impact needs further study.

Promoters are a kind of farmer extension agent, which are popular in Central America, thanks to the development organization World Neighbours and other institutions. They are a low cost, personal way of reaching many people, which allows the technology to be adapted by the people who will use it.

In Bangladesh, one innovative NGO, Shushilan, used 'picture songs' (about 20 minutes of songs and a very large painting on a scroll) as a kind of moving picture, to teach appropriate rice technology to thousands of people, especially about natural enemies and using organic fertilizer. As a performer sings out the message (and dances), the rest of the troupe accompanies her with music, and rolls out the illustrations on the scroll. Hundreds of people can see each memorable performance at one sitting.

Videos have been used in Bangladesh, combined with farmer participatory research, and community meetings. Researchers at RDA (Rural Development Academy) developed appropriate rice seed technology with farmers (e.g. drying rice seed on a bamboo table, keeping seed dry in a painted pot). Then they made videos where farmers spoke on camera. Their honest words were convincing to other farmers, who could identify with them[1,2].

Plant health clinics are a new extension method being implemented in Nicaragua, Bolivia, Uganda, Bangladesh and elsewhere, pioneered by the Global Plant Clinic. The plant clinics provide a place for personalized consultations between farmers and agronomists. The plant clinics can be easily combined with other methods like FFS, fact sheets, radio, short courses, etc.[3].

'Going Public' is another face to face method for a mass audience. An extensionist goes to a market or another crowded place, and delivers a short message, and then repeats it. It is especially well suited to rather simple messages that must show something (e.g. a disease symptom, a new tool)[4].

Written material, including fact sheets, journals and newspapers are also useful, especially when written for farmers and validated by farmers before distribution.

Radio is a promising method, and has been used recently in Vietnam to teach people to avoid insecticide abuse in rice. A project using radio, leaflets and other media led to a 53% reduction in insecticide use and no loss in production in project sites, and the change eventually spread to more than a million rice farmers three years later[5].

The challenge is to fine-tune technologies with farmers (e.g. using FFS), and then extend the techniques with a mix of mass media and other methods. An example from two Colombian biocontrol experiences suggests why this is important

When the coffee berry borer (*Hypothenemus hampei*) entered Colombia in the early 1990s, researchers were keen to find an alternative to chemicals. They tried the entomopathogenic fungus *Beauveria bassiana* (*Bb*), which failed. The Colombian coffee sector has excellent extensionists, who duly taught farmers how to make *Bb*, but it was too difficult for them to make enough of it in their kitchens, and after trying it, they abandoned it. Researchers also brought parasitic wasps from Africa, which did become established, but which parasitized only 5% of the berry borer population[6,7].

Through rigorous studies, entomologists knew that the borer only lived in coffee berries. So by gathering up all berries from the ground and by gleaning over-ripe fruit from the trees, the growers could eliminate the pest's habitat. Researchers called the gleaning-plus-clean harvest 'Re-Re'. Extension agents taught Re-Re, but farmers would not pick fallen fruit from the ground. The hillsides were usually so steep that bending over was uncomfortable and could lead a person to slip or fall; the fallen fruit was often hidden by leaves. The berries on the ground were often rotten and could not be sold. But farmers did begin to make more of an effort to harvest all the coffee berries from the trees (clean harvest), because the good berries could be sold, which usually paid for the labour to pick them. At first researchers and extensionists were displeased that farmers were modifying Re-Re, but they eventually realized that the farmer modifications made the technology more acceptable, that clean harvest was being adopted, and it was controlling the pest[8].

Clean harvest is also being used by farmers to control the coffee berry borer in other parts of Latin America and in India. Even though Re-Re is a low, unglamorous technology, farmer modifications made it simple and functional enough so that others would use it. But of course farmers made these improvements after researchers gave them some basic ecological background information (e.g. coffee berry borers only live in coffee fruit) as well as a prototype technology. FFS is eminently suited to conveying biocontrol messages and collaborating with farmers to hone the technology, which can then be communicated to the farming public through mass media and extension.

[1]Van Mele, P., Zakaria, A.K.M. & Bentley, J.W. (2005) Watch and learn: video education for appropriate technology. In: Van Mele, P., Salahuddin, A. & Magor, N.P. (eds) *Innovations in rural extension: case studies from Bangladesh*. CABI and IRRI, Wallingford, UK, pp. 77–88.

[2]Van Mele, P. (2006) Zooming-in, zooming-out: a novel method to scale up local innovations and sustainable technologies. *International Journal of Agricultural Sustainability* **4**(2), 131–142.

[3]Danielsen, S., Boa, E. & Bentley, J.W. (2006) Puesto para plantas: a clinic where you can bring your sick plants. Funica, Managua, Nicaragua.
Web: www.funica.org.ni/docs/Book-PPP-Eng.pdf (accessed 6 February 2008)

[4]Bentley, J.W., Boa, E., Van Mele, P., *et al.* (2003) Going public: a new extension method. *International Journal of Agricultural Sustainability* **1**(2), 108–123.

[5]Escalada, M.M. & Heong, K.L. (2004) The case of using mass media: communication and behavior change in resource management. In: *New directions for a diverse planet. Proceedings of the Fourth International Crop Science Congress*. Brisbane, Australia.

[6]Baker, P.S. (1999) *The coffee berry borer in Colombia*. CABI Bioscience, Ascot, UK. 144 pp.

[7]Bentley, J.W. & Baker, P.S. (2002) *Manual for collaborative research with smallholder coffee farmers*. CABI Commodities, Egham, UK. 130 pp.

[8]Aristizábal A., L.F., Salazar E., H.M. & Mejía M, C.G. (2002) Cambios en la adopción de los componentes del manejo integrado de la broca del café, *Hypothenemus hampei* (Coleoptera: Scolytidae), a

través de metodologías participativas con agricultores. *Revista Colombiana de Entomología (Colombia)* **28**(2), 153–160.

**This article is a summary of: Bentley, J.W. (2009) Impact of IPM extension for smallholder farmers in the tropics. In: Peshin, R. & Dhawan, A.K. (eds)* Integrated pest management. Vol. 2. Dissemination and impact. *Springer, New York, pp. 333–346. See New Books section, this issue.*

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Mass Media Participatory Extension in Vietnam

The value of the participatory process in honing mass media extension campaigns was illustrated by a paper published in late 2008[1], which analysed activities undertaken in Vietnam's Mekong Delta aimed at persuading rice farmers to reduce inputs and consequently realize increased profits.

Mass media extension in this region began during the 1990s when a radio drama was used to spread the message that early insecticide spraying against leaf-feeding insects in rice crops was a waste of money, a message devised by national researchers and extensionists. Farmers erroneously believed that leaf feeders were economically damaging, but spraying them actually disrupted the natural enemy complex that helped regulate later and more significant pests, such as brown planthopper (*Nilaparvata lugens*). The radio drama was followed up by village-based meetings and crop trials. The message reached some two million farmers and persuaded them to change their spraying practices; insecticide use was more than halved while rice yields remained unchanged [see *BNI* 23(3), 74N–75N (September 2002), 'Radio's dramatic impact', and article above, this issue]. Other provincial governments subsequently adopted the approach.

The new initiative has built on that success and persuaded farmers to cut seed rates and fertilizer applications as well as insecticide applications. Rice farmers in the Mekong Delta have high seeding rates and fertilizer use, perhaps believing they increase yields, but these levels are above optimum levels indicated by research for crop growth and are instead associated with increased vulnerability to pests and diseases. The project team reasoned that if they could persuade farmers to reduce the amounts of these inputs, they would need less pesticide (which would also benefit natural enemies) and profits would be higher because the cost of crop inputs would be lower. Pilot trials with volunteer farmers showed that yields were maintained despite reducing seed, nitrogen and insecticide rates, while profits were increased in both wet and dry seasons.

The team used a participatory planning process to develop and refine a mass media campaign intended to modify crop management practices. The team came up with a name for the campaign, 'Ba Giam – Ba Tang' or 'Three Reductions – Three Gains', which was launched in Can Tho and Tien Giang provinces. Pre- and post-campaign surveys were conducted with farmers from both provinces, who were far from being novices: they had an average of 22 years experience of rice farming.

Most farmers heard about the campaign (86% and 56% in Can Tho and Tien Giang, respectively) and from several sources. The most commonly encountered way of receiving the message, in terms of percentage farmers reached, was a TV drama (60% and 28%), with a leaflet, a poster, and neighbours/friends also playing a significant role in spreading the message. In both provinces farmers correctly perceived the campaign's main themes.

The campaign message was translated into practice, with farmers' use of all three inputs falling between pre- and post-campaign surveys in both provinces (although for fertilizers this was mostly for nitrogen; and while insecticide use fell, results for fungicides and herbicides were mixed). Perceptions of yield losses were altered, with farmers in both provinces estimating their losses as lower after the campaign had led them to reduce inputs. Moreover, the pre-survey common belief that high inputs were 'modern' and equated to high yields was modified by the campaign and indicated that the messages had been accepted.

The main motivational message in the campaign was that reduced inputs would mean higher profits because rice production would be maintained or increased, and this assertion was fulfilled: average net profits increased by US$58/ha/season. More than 70% of net profits came from savings in pesticide costs, which motivated farmers to reduce seed and fertilizer rates. Nonetheless, rates of these two inputs are still higher than recommended so more savings could be made.

Since this work was done, several provincial governments and the Ministry of Agriculture and Rural Development have provided resources for further dissemination of the campaign message.

[1]Huan, N.H., Chien, H.V., Quynh, P.V., Tan, P.S., Du, P.V., Escalada, M.M. & Heong, K.L. (2008) Motivating rice farmers in the Mekong Delta to modify pest management and related practices through mass media. *International Journal of Pest Management* **54**(4), 339–346.

Contact: K.L. Heong, International Rice Research Institute, Los Banos, Metro Manila, Philippines.
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Announcements

Are you producing a newsletter or website, holding a meeting, running an organization or rearing a natural enemy that you want biocontrol workers to know about? Send us the details and we will announce it here.

SIP in Utah

The 42nd Annual Meeting of the Society for Invertebrate Pathology (SIP) will be held in Park City, Utah, USA on 16–20 August 2009. The plenary symposium, 'The host-pathogen dance: interactions between insect hosts and their pathogens', will include presentations by Bruce Tabashnik, Michael Bidochka and Michael Strand. Divisional symposia will cover Bacteria (including '*Bacillus thuringiensis* resistance in the real world'; '*Bacillus thuringiensis*, the bacterium, ecology and infection'); Beneficial invertebrates; Fungi ('Fungi in soil habitats'; 'Insect defense responses to fungal pathogens'); Nematodes ('Ecological interactions in entomopathogenic nematodes'); Microbial control ('Biopesticides in strawberries and vegetables: available and potential technologies'); Microsporidia ('Microsporidia of beneficial arthropods'); and Viruses ('Insect RNA viruses: advances and applications'; 'Invertebrate anti-virus response'; 'The viral face of PDVs: origin and structure of the chromosomally integrated PDV genomes').

Cross-divisional symposia will include: 'Multitrophic interactions: implications for invertebrate pathogens'; and 'Epizootiology and its impact on microbial control: honoring the work of Jim Fuxa'.

There are also planned workshops for students (a praised inclusion last time, this time covering how to get a postdoc position and get into the scientific network); and on bacteria ('*Bt* resistance mechanisms other than loss of toxin binding'); microsporidia ('Staining techniques used for microsporidia infecting invertebrates'); and viruses ('Advances in invertebrate cell culture').

Although abstract submission is now closed, you can get early registration until early July, and late registration is available until just before the meeting.

Contact: Conference Co-chairs, Donald W. Roberts (Department of Biology) & Rosalind James (USDA-ARS Pollinating Insect Res. Unit, Dept. Biology), Utah State University, Logan, UT 84322, USA.
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Island Invasives Meeting Reprised in New Zealand

An international conference, 'Island invasives: eradication and management' is to be held at Tamaki Campus, University of Auckland, New Zealand, on 8–12 February 2010, organized by the Centre for Biodiversity and Biosecurity (University of Auckland & Landcare Research), in collaboration with the IUCN/SSC Invasive Species Specialist Group. The conference will continue, and expand on, the theme of the very successful one held in 2001: 'Eradication of island invasives'.

The intention is to bring together people from around the world working on all aspects of the topic, to enable them to share knowledge and experiences; future work will be encouraged. Satellite meetings before and after the conference are also encouraged.

The conference will have 'islands' and 'eradication of invasive species' as the focus, with emphasis on the work done and results or learning achieved; it will aim to cover the full breadth of the subject: gaining political, community, financial and physical support; eradication techniques tested and used; immediate results of eradication operations; longer-term outcomes (as seen in biota of the island and among communities involved); and biosecurity measures for islands from planning to implementation.

It is proposed to organize the conference into general sessions presenting eradication actions and five themes: 'Ecological outcomes of eradications'; 'Social and economic dimensions of eradications'; 'Managing reinvasion risks'; 'Eradicating multiple pest species'; and 'New techniques and approaches'.

The organizers are calling for abstracts for oral and poster presentations (deadline 31 August 2009). Registration for attendance opens in June 2009.

Information: Dick Veitch.
Email: dveitch@kiwilink.co.nz
Web: www.cbb.org.nz/conferences.asp

International Conference on Biopesticides in India

Following the success of the first conference in 2007, the Second Biopesticide International Conference (BIOCICON-2009) will be held on 26–28 November 2009, once again in Palayamkottai in the Indian state of Tamil Nadu. It is being organized and held by the Crop Protection Research Centre, Department of Advanced Zoology and Biotechnology of St Xavier's College, and promoted by the Department of Science and Technology (DST), New Delhi; Council for Scientific and Industrial Research (CSIR), New Delhi and Tamil Nadu State Council for Science and Technology (TNSCST), Chennai.

BIOCICON-2009 aims to promote basic and applied research and development for ecofriendly pest and disease management in agriculture, horticulture and forestry, with the mantra of organic crop production and protection for sustained and safe food supply. It will include sessions covering the following topics: 'Pests: Microbes and animals – diversity, bionomics, impacts on crops'; 'Microbes: bacteria, fungi, virus, nematodes – formulations and applications'; 'Natural enemies: predators, parasitoids – biology, bioefficacy, augmentation'; 'Evaluations and biosafety on non-target organisms'; 'Botanicals: isolation, formulation, evaluation and integration'; and 'Biotechnology – product developments: biotechnology, nanotechnology, semio-chemicals, GM crops, eco-friendly agrochemical based industries and IPM'.

Organizers are calling for abstracts (deadline 28 July 2009) and registration (15 August). Papers presented in the conference will be reviewed and published in the *Journal of Biopesticides* as a special issue

Web: www.idosi.org/conferences/
BIOCICON%20circular-one.pdf

Contact: Dr K. Sahayaraj, Organizing Secretary 'BIOCICON-2009', Crop Protection Research Centre, Department of Advanced Zoology and Biotechnology, St Xavier's College (Autonomous), Palayamkottai – 627 002, Tamil Nadu, India.
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Arid and Semi-arid Environments Weeds Tackled in Greece

The Second International Conference on Novel and Sustainable Weed Management in Arid and Semi-Arid Agro-Ecosystems will take place in Santorini, Greece on 7–10 September 2009, under the auspices of the European Weed Research Society. Among a wide variety of topics, those relevant to *BNI* readers include: 'Weed biology, ecology and modeling'; 'Invasive weeds: biology, control and quarantine regulations'; 'Integrated weed management in arid and semi arid farming systems: dry-land crops and irrigated crops'; 'Cultural, physical and biological weed practices'; and 'Parasitic weeds'. In addition there will be a special topic: 'Direct and indirect effects of climatic changes on weed occurrence'.

Information: Organizing Committee.
Email: economou@aua.gr or htravlos@yahoo.gr

EWRS Symposium in Hungary

The 15th EWRS (European Weed Research Society) Symposium will take place in Kaposvár, Hungary on 12–15 July 2010, and the organizers welcome abstract submissions (deadline 15 September 2009) and suggestions for workshop topics. Contributions will be refereed and published in the conference proceedings.

Information: Symposium Secretariat,
ASSZISZTENCIA Congress Bureau,
Hegedus Gy. u. 20., H-1136 Budapest, Hungary.
Email: ewrs@asszisztencia.hu
Fax: +36 1 350 0929
Web: www.asszisztencia.hu/ewrs

Gabriella Kazinczi, EWRS national representative, Kaposvár University, Faculty of Animal Science.
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Australian E-Bulletin on Invasives and Climate Change

Readers around the world might take a look at *Double Trouble*, a new online publication from the Australian Invasive Species Council as part of its Pests and Climate Change Project. The aim of the e-bulletin is to convince decision and policy makers of the urgent need to prepare for the combined dangers of climate change and invasive weeds and pest animals, many of which are expected to thrive in the extreme weather events predicted under climate change. As such it could well spawn similar publications elsewhere.

The range of topics in the first (February 2009) issue includes bushfires, *Phytophthora* root disease and biodiversity hotspots, commercial lawn species, biofuels, and antarctic microbes; specific threats such as hawkweeds, bitou and cane toad are covered, and a number of articles deal with Australian and international policy and research.

Web: http://doubletroublebulletin.wordpress.com

Contact: Tim Low, Invasive Species Council
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Predatory Mite Family Revision

The newsletter from ARC-PPRI (Agricultural Research Council – Plant Protection Research Institute), South Africa, has highlighted how phytoseiid mite taxonomists around the world have, since 2001, revised members of this group from sub-Saharan Africa. These include predators that have been extensively used for biological control of mite and insect pests on a number of crops globally – including the classical biological control of cassava green mite (*Mononycellus tanajoa*) in Africa, during which programme phytoseiid identification was a major problem[1].

The revision of the family resulted in nine taxonomic papers, reporting on 27 genera and 277 species of which 68 were described for the first time and 170 were re-described. The first paper was published in 2001 and the ninth and last paper was published at the end of 2008.

[1]Anon. (2008) Revision of important predatory mite family from Africa completed. *PPRI News* No. 78 (Oct–Dec 2008), p. 4. Newsletter of the Plant Protection Research Institute (PPRI), an institute in the Natural Resources and Engineering Division of the Agricultural Research Council (ARC) of South Africa.
Web: www.arc.agric.za/
home.asp?pid=376&toolid=2&sec=774

Predicting Plant Invasions across Europe

A recent paper in the journal *Diversity and Distribution*[1] presents the first map for predicting the level of invasion by alien plants across Europe, which could help policy makers design conservation policies suited to different habitats and landscapes. Areas dominated by farming and urban land are among those identified as particularly at risk. In terms of climate, areas most under threat from invasion are moderately dry and warm lowland areas of western Europe as well agricultural regions in central and eastern Europe.

This was an output of the ALARM project (Assessing LArge scale Risks for biodiversity with tested Methods), funded by the European Commission Sixth Framework Programme. (www.alarmproject.net).

[1]Chytry, M., Pysek, P., Wild, J., *et al.* (2009) European map of alien plant invasions based on the quantitative assessment across habitats. *Diversity and Distribution* **15,** 98–107.

Source: EC Directorate-General for Environment News Alert Service. SCU, The University of the West of England.

Conference Reports

Have you held or attended a meeting that you want other biocontrol workers to know about? Send us a report and we will include it here.

ISBCA III in New Zealand

The Third International Symposium on the Biological Control of Arthropods (ISBCA) was held in Christchurch, New Zealand over 8–13 February 2009. Local organizers for the conference included Steve Wratten, Mattias Jonsson, Marco Jacometti, Sara Russell, Tereska Kozera, and Anna-Marie Barnes. Financial support for ISBCA III was provided, in part, by BioProtection Research Center, Plant and Food Research New Zealand, VsNi Australia, Bayer CropScience, New Zealand, Westpac New Zealand, Brill The Netherlands, and the USDA (US Department of Agriculture) Forest Service through Dick Reardon who sponsored the mass production of the ISBCA III conference proceedings.

The meeting was opened in spectacular fashion with a powhiri, a traditional Maori welcome to visitors. The traditions and protocol of the powhiri provided visitors to ISBCA III a unique insight into the spiritual world of the Maori, the indigenous people of New Zealand. The meeting was attended by 168 people from 28 different countries (New Zealand with 43 representatives; USA 37; Australia 15; Canada 10; Spain 9; Switzerland 7; Japan 5; UK, Sweden and the Netherlands four each; Czech Republic, Taiwan, China, and Chile three each; Israel, Austria, Belgium, South Africa, two each; Mexico, South Korea, India, Egypt, French Polynesia, Oman, Philippines, Nigeria, Germany, and Denmark were each represented by one attendee.)

Selection of session topics for ISBCA III was guided by input from a seven member Scientific Committee, with representation from New Zealand, Switzerland, UK, Benin, India, and the USA. ISBCA III consisted of 15 sessions that covered:

- New and emerging successes in classical biological control: has theory improved practice?
- Biological control and climate change
- Exploring biological control to manage new or potential invasive pests
- Molecular tools in biological control
- GMOs and biological control
- Impact of landscape composition and structure on natural enemies
- Recent advances in conservation biological control
- Omnivory in biological control
- The role of theory in greenhouse biological control
- Biological control of phytophagous mites: theory and practice
- Attributes of exotic biological control agents: the good and the bad
- Inducible plant responses and impact on biological control of plant pests
- Food web interactions and impact on biological control
- Progress and prospects to assess predation
- Capacity building through action learning in region wide biological control

In addition to the talks presented in each session, 123 posters relating to the sessions were also presented. The ISBCA III conference proceedings, edited by Peter Mason, David Gillespie and Charles Vincent with Agriculture and Agri-Food Canada, and published with support from USDA Forest Service Forest Health Technology and Enterprise Team have excellent detailed synopses of presented talks and abstracts from posters. The published Conference Proceedings are 636 pages in length, and 100 hardcopies are available from Annie Barnes (annamarie.barnes@lincoln.ac.nz) or downloadable from the web (www.biocontrol.ucr.edu/ISBCA/3). Downloadable copies of proceedings for ISBCA I held in Hawaii, 14–18 January 2002 (www.biocontrol.ucr.edu/ISBCA/1) and ISBCA II held in Davos, Switzerland, 12–16 September 2005 (www.biocontrol.ucr.edu/ISBCA/2) are also available free of charge.

Two simultaneous field trips were held on the afternoon of the third day of the meeting. One involved a bird watching expedition to Lake Ellesmere, and the second to the organic trial farms at Lincoln University. After the field trips a cricket match and dinner with entertainment from local jazz musicians wrapped up the evening. ISBCA III had three notable additions to the meeting format that added a lot of additional entertainment to the symposium. First, students were encouraged to participate in giving talks in the sessions or to present their work as a poster. A panel of three judges, Mark Hoddle, Roy Van Driesche and Ulli Kuhlmann, assessed student talks and posters over the course of the meeting. Cash prizes and text books on biological control were awarded to the first and second placed. Students representing Nigeria, Germany, Australia, New Zealand, and the USA collected prizes. Second, a lively and passionate debate between Tony Shelton and Miguel Altieri on the role of genetic engineering and genetically modified organisms (GMOs) was moderated by Steve Wratten. The subject of the debate was 'GMOs should have no place in biological control!' Third, the official ISBCA III banquet dinner was made very memorable by a 'Trivial Pursuits' tournament between tables where the objective was to answer correctly as many obscure questions as possible pertaining to entomology, b-grade horror movies, famous people, and geography. A cash prize was awarded to the winning table!

Presentations for the ISBCA IV venue were made on the last day of the meeting with delegates reviewing presentations from ICIPE in Kenya, and cooperating research institutes in Chile. The majority ruled in favour of having ISBCA IV in Chile in 2013. ¡Les veo en Chile mis amigos!

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International IPM Symposium in Oregon

The Sixth International IPM Symposium 'Transcending boundaries' was held in Portland, Oregon on 24–26 March 2009. This outstanding conference provided an opportunity to share the world's latest advances in managing pests in ways that are cost effective and protect human health and the environment. There were more than 700 participants from 29 countries, confirming its designation as the first 'International' IPM Symposium. A historical overview of the National and International IPM Symposia from 1989 to 2009 is given in the next section.

The Sixth Symposium began with a plenary session in which Dan Gerling, Department of Zoology, Tel Aviv University, Israel, spoke on 'Fostering IPM and international understanding in the Middle East'. He was followed by Janjo de Haan, Wageningen Research Center, The Netherlands, who delivered a presentation on 'Integrated crop protection as a part of farming system design'. Next, Pierce Jones, Program for Resource Efficient Communities, University of Florida, described 'Master planned community developments and IPM' and finally Sara J. Scherr, Ecoagriculture Partners, Washington, D.C., concluded with 'IPM strategies in ecoagriculture landscapes: the challenge and opportunities of coordinated pest management for products and ecosystem services'.

The Symposium programme was carefully crafted to incorporate the best available IPM information. There were 67 regular sessions, 194 posters, 28 exhibitors and a considerable number of both scheduled and unscheduled side meetings in the mornings and evenings. The regular sessions, posters and side meetings addressed the following subjects, some more than once and from different perspectives:

- *Challenges*: global food shortages, delivering IPM, international cooperation, IPM road map, municipal pesticide laws, IPM education, economics, invasive alien species
- *Strategies*: green revolution, eXtension, integrated crop management, regional food systems, pesticides in surface waters, landscape level IPM, area-wide IPM
- *Applications*: insect-transmitted plant viruses, best management practices, invasive species, environmental stewardship, vegetation management, water and soil quality, plant nutrition and diseases
- *Pests*: termites, bed bugs, thrips, bark beetles, ants, migratory insects
- *Crops*: corn, soybeans, genetically modified, organic, biofuels
- *Communities*: schools, child care facilities, green buildings
- *Pesticides*: biorationals, risks, resistance, biopesticides, evaluation, biofumigation
- *Marketing*: IPM in retail stores, eco-labelling, food industry, branding IPM, pest management industry
- *Technologies*: geographic information systems, IPM impacts

A new, creative activity was to conduct brainstorming sessions on selected topics with the goal of generating actions to be accomplished before the next Symposium. The four topics selected for this conference were 'Integrating IPM with the design of cropping systems: a multifunctional approach', 'Branding IPM', 'Education and training in IPM', and 'IPM adoption: keys to implementing IPM and gaining its full benefits'.

At the special awards ceremony, International IPM Excellence Awards were presented to the USAID (US Agency for International Development) IPM Collaborative Research Support Program (CRSP), SYSCO Corporation, and Green Shield Certification Program, plus Dr Zeyaur R. Khan, ICIPE, Nairobi, Kenya, and the Salt Lake City School District, Utah. The Lifetime International IPM Achievement Award was received by the Bio-Integral Resource Center of California. The International IPM Awards of Recognition were awarded to the Santa Clara County, California, Grower Incentives for IPM Team Project and the International Team for Sustainable Adoption of Eggplant IPM in South Asia.

Biological control was emphasized more than in the past before, during and after this Symposium. A day and a half joint meeting of the southern (S-1034) and western (W-2185) US regional biological control projects preceded the Symposium (reported in the last section of this article, below). Also included were separate business meetings with the usual state reports on biological control projects. Another pre-Symposium meeting was an update on the USDA-ARS (US Department of Agriculture – Agricultural Research Service) Overseas Biological Control Laboratories. Additionally, there was a USAID-IPM-CRSP Technical Committee Meeting. The opening reception and dinner at the World Forestry Center Museum featured Dan Gerling's IPM programme on red palm weevil and natural enemies of the olive fruit fly. During the Symposium, the Association of Natural Bio-control Producers conducted a brainstorming session, 'IPM implementation: forging stronger partnerships between biocontrol producers, researchers and agricultural clientele'. Another session was 'Creating temporal and spatial refugia for biological control in tree fruits'. Regional and multiregion IPM coordinator meetings were held both before and after the Symposium, primarily to discuss the new USDA-CSREES (Cooperative State Research Education, and Extension Service) Extension IPM Coordination and Support Program that funded state IPM programmes in the past. Also after the Symposium, and with limited relevance to biological control, was a USDA-CSREES Regional Project Meeting (WERA060) on 'Management of pesticide resistance'.

The Sixth International IPM Symposium website contains the programme, abstracts and other pertinent information, and will have reports as they are provided (www.ipmcenters.org/ipmsymposium09/). The website acknowledges the many contributions of sponsors, participants and volunteers who supported this superb conference. The IPM community appreciates all that these contributors have provided and seeks volunteers to assist with the next Symposium.

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*Historical Overview of the International IPM Symposium**

The integrated pest management (IPM) concept grew out of concerns about reliance on pesticides that began in the 1950s. Pests were becoming resistant to pesticides and alarming side effects began to appear. Rachael Carson and other writers and journalists alerted the public about the consequences of pesticide misuse and over-use. The federal government responded by revising pesticide laws, creating the EPA (Environmental Protection Agency) to administer associated pesticide regulations, and funding national IPM initiatives. The International IPM Symposium evolved from one of those initiatives.

1989 – 1st National IPM Symposium, Las Vegas, Nevada: 'Targeting research for IPM implementation' and increasing awareness and support for IPM. Pesticide use had increased dramatically.

1992 – National IPM Forum, Arlington, Virginia: 'A national commitment to IPM' and establishment of a formal inter-agency IPM task force. It provided a forum for scientists engaged in IPM to interact with administrators and policy makers, and bridged the gap between IPM Symposia. This led the Clinton Administration, as part of its comprehensive pesticides policy, to call for implementation of IPM on 75% of America's cropland by the year 2000.

1994 – 2nd National IPM Symposium, Las Vegas, Nevada: 'IPM programs for the 21st century: food safety and environmental stewardship'. It addressed reducing environmental problems, ensuring a safe, healthy, and plentiful food supply, and assisting with sustainable agriculture.

1996 – 3rd National IPM Symposium, Washington, D.C: 'Putting customers first and assessing IPM program impacts'. Adoption of IPM practices requires increased leadership, coordination, funding, delivery, and evaluation. Use of high risk pesticides remained prevalent. The Government Accounting Office issued a report, 'Management improvements needed to further promote IPM'.

2003 –- 4th National IPM Symposium, Indianapolis, Indiana: 'Building alliances for the future of IPM'. The 'National Roadmap for IPM' was produced to increase nationwide communication and efficiency through information exchange among federal and non-federal IPM practitioners and service providers, including land managers, growers, structural pest managers, and public and wildlife health officials.

2006 – 5th National IPM Symposium, St. Louis, Missouri: 'Delivering on a promise'. Developments were made in improving the economic benefits of adopting IPM practices and reducing potential risks to human health and the environment caused by the pests or pest management practices. Leadership was expanded to include the private sector, international members, numerous federal agencies, and universities.

2009 – 6th International IPM Symposium, Portland, Oregon: 'Transcending boundaries'. This global Symposium had more than 700 participants from 29 countries who presented sessions on IPM challenges, strategies, and applications; applying IPM for pests, crops, and communities; and the latest information on pesticides, marketing and new technologies for use in IPM. It is the first International IPM Symposium that especially recognized the importance of global cooperation and impact of alien invasive species.

*Adapted by Norman C. Leppla (University of Florida) from talks presented by Michael E. Gray, University of Illinois, and Frank G. Zalom, University of California, in 2006 at the Fifth National IPM Symposium in St Louis, Missouri (www.ipmcenters.org/ipmsymposiumv/)

Southern and Western Region Multi-State Biological Control Projects Joint Meeting

US multi-state projects bring together scientists working on common problems within four regional blocks: western, southern, north-central and north-east regions (http://nimss.umd.edu/). Participants in multi-state projects meet annually, and for the first time, the southern and western regional biological control projects held a joint meeting just ahead of the International IPM Meeting in Portland, Oregon. The southern region project (S1034), 'Biological Control of Arthropods and Weeds' encompasses the following states: New Jersey, Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Oklahoma, Virginia and Texas (http://nimss.umd.edu/homepages/home.cfm?trackID=7456). The western region project (W2185) 'Biological Control in IPM Systems for Plants' covers the following participating or collaborating states: Kansas, Delaware, New Jersey, New York, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Oregon, Washington (state), Wyoming and Utah (http://nimss.umd.edu/homepages/home.cfm?trackID=9596). Given the huge number of invasive alien species entering the USA through the southern and western regions, a large number of biological control activities are found in these states. This year's meeting was attended by 78 participants and had 25 presentations distributed among six topics: 'Agency updates', 'The new regulatory environment for biocontrol', 'Implementing biological control', 'Role of predators in biological control', 'Ecology and evolution of arthropod biological control by parasitoids', and 'Weed control by arthropods: challenges for ecology and conservation'. The full agenda and presentations from the meeting can be viewed on the following webpage: http://nature.berkeley.edu/biocon/W1185%20Officers.htm

By: Dr Moses T.K. Kairo (Chair S1034)[a] & Dr. Peter B. McEvoy (Chair 2185)[b]

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Second IOBC Meeting for the Integrated Control of Plant Feeding Mites

The IOBC (International Organization for Biological Control) has various working groups which meet regularly to present new findings and discuss future areas of research. Working group meetings aim to encourage collaboration of scientists working on common problems, share experiences and increase the general knowledge of its members in the area of interest. The plant feeding mites working group was formed in 2007 and the second meeting of the newly formed group was held in Florence, Italy, on 9–12 March 2008 at CRA (Consiglio per la Ricerca e la Sperimentazione in Algricoltura). The meeting was split into several sessions, which were moderated by various experts in their fields; the sessions were 'Phytoseiid types in biological control', 'Chemical control', 'Exotic and non-tetranychid pests', 'Behavioural effects in biological control', 'Pest management in vineyards' and 'Plant pest interactions'.

Session 1 on phytoseiid types in biological control was moderated by Jim McMurtry, who also gave the keynote lecture on phytoseiid use in biological control, taxonomic classification and lifestyle categorization. Prof McMurtry has spent over 50 years studying mites and presented a paper classifying predatory mites into different lifestyle niches. Predatory mites can be split into at least four different life style categories ranging from specialists (Types I and II) to generalists (Types III and IV). 'Body plan' may have an influence on the specialization of the mites. For example he raised the question as to whether the length of certain setae were related to an association with spider mite webbing in specialists and also whether, for generalists, body plans exerted such an influence that predators were more adapted to host plant characters than prey.

The next few talks focused on enhancing the effectiveness of predators by using conservation techniques and the use of novel pollen application. Conservation techniques focused on increasing the amount of available pollen in the surrounding areas, for example intercropping in orchards with high pollen producing plants. Other methods of increasing available pollen included electrostatic spraying of pollen onto crops. By increasing the available pollen to optimal amounts, it has been shown to be beneficial to the predatory mite fauna as generalist mite predators use pollen as an alternative food source. It was also shown that pollen could be used to establish higher numbers of predators in the field meaning the predators are well established before the pest arrives.

The session on chemical control highlighted that methyl bromide fumigation treatments were failing to completely kill mites in grape samples sent from Chile to Mexico. A talk by Gabriel Otero-Colina (Instituto de Fitosanidad, Mexico) showed that quarantine mite pests on grapes were able to survive fumigation with methyl bromide (sent from Chile), therefore highlighting the need for further research into alternative methods of pest control or improving the efficacy of current techniques for foodstuffs passing between borders in South America.

Session 3 focused on exotic and non tetranychid mite pests. The keynote speaker was Jorge Peña who works for the University of Florida . Dr Peña gave a talk on the results of his research on the invasive mite pest *Raoiella indica* (red palm mite, RPM) and the response of native natural enemies to its introduction into the Caribbean and Florida. Being based in Florida, surveys were carried out prior to and post the introduction of *R. indica*. Their surveys were able to gauge the response of indigenous natural enemies to the arrival of the new prey species. Predator density did not increase until six months after the arrival of RPM in Florida, and in Trinidad, *Amblyseius largoensis* (a predatory mite) increased in numbers alongside RPM numbers. Dr Peña gave a comprehensive list of predators found in association with RPM and details are available in the conference bulletin. This work complemented the following talk given by Bryony Taylor (CABI), which focused on the surveys carried out in India since November last year for RPM and natural enemies as part of preliminary studies for a classical biological control programme.

Aceria carvi was also talked about in this session as a potential threat to caraway in Europe. Dr R. Zemek of the Institute of Entomology (Czech Republic) gave a talk highlighting the substantial increase in caraway crops grown in Europe over the past few years and underlined the importance of carrying out more research on this pest, as there is no effective way of controlling it currently.

Session 4, moderated by Maurice Sabelis, encompassed many talks on the behavioural effects of biological control. Prof. Sabelis gave a very interesting talk on multiple predators and intraguild competition in relation to the control of spider mites. This session bought up interesting subjects such as how habitat structure can have an effect on pest management systems. Different species of predatory mites may be found in different niches in plants; for example, in cassava the predators differ between the apex and lower leaves. The apex inhabiting predator was also found to be more active nocturnally adding another dimension to improvements for sampling. Peter Schausberger of the University of Natural Resources and Applied Life Sciences, Vienna (Austria), stated that the ability of prey to use spatial refugia is a key issue for the currently insufficient natural and biological control of *Tetranychus evansi* and *Aceria guerreronis*. Refugia may be sought by prey; for example, the coconut mite (*A. guerreronis*) finds refuge between the perianth and the coconut surface. *Aceria guerreronis* has a competitive advantage against predators, as these refugia are too small for predators to access until pest populations are well established and the perianth separates slightly from the coconut. *Tetranychus evansi*, a pest of tomatoes, has a competitive advantage by specializing on tomatoes, as this host plant exerts direct and indirect prey mediated negative effects on the mite's predators.

Session 5 focused on pest management in vineyards and was moderated by Carlo Duso, of the University of Padua, Italy. Professor Duso gave an overview of the relationships between plant pathogenic fungi and mites in vineyards for his keynote lecture, relating it to the implications for IPM. Interestingly the talk linked the disease *Plasmopara viticola* (grapevine downy mildew) to an increase in phytoseiid and tydeid mites in European vineyards, with *Amblyseius andersoni* populations showing a clear response to the spread of the disease. The effects of powdery mildew (*Uncinula necator*) were less pronounced. It was shown that pollen was important for early season establishment of predatory mites; however, mildews increase in importance in late summer and he went on to suggest that downy mildew may enhance the recovery of predatory mite populations following pesticide applications. Other talks covered biological control and the use of acaricides in vineyard systems.

The final session covered plant–pest interactions and was moderated by Gerben Messelink from Wageningen UR Greenhouse Horticulture, in the Netherlands. His talk focused on indirect host-mediated defences on spider mite populations (*Tetranychus urticae*) induced by the presence of whitefly populations (*Trialeurodes vaporarium*) on the host plant. This work showed a 30% reduction in mite population growth when they were present on whitefly infested cucumbers compared to a control. It was also found that the release of predators was subsequently more effective in curbing mite populations on whitefly infested plants. Possible hypotheses for these responses include the production of pathogenesis related proteins by the cucumber plant. Other talks in this session looked at the homogeneity of pest populations in orchards and host plant effects on predators in relation to their prey.

The conference was an invaluable experience for people working in this area of research to discuss ideas and learn more about cutting edge research on the periphery of their own. Special thanks are to be extended to the conference organizers at CRA led by Sauro Simoni, in cooperation with Marialivia Liguori, Marisa Castagnoli and Roberto Nannelli, and the working group convener Eric Palevsky.

By: Bryony Taylor, CABI.

ESA 2008

The annual meeting of the Entomological Society of America (ESA) was held on 16–19 November 2008 in Reno, Nevada. The meeting was well attended, with 2446 people registered for the meeting, including 678 students who presented 422 student competition talks and posters. The Founders' Memorial Lecture was delivered by Dr Allan Felsot of Washington State University, to honour the multidisciplinary accomplishments of Robert L. Metcalf. President Mike Gray reported in his plenary speech that 48 member Networks have been created over the past year. He also elaborated on potential collaborations between ESA and other related scientific societies as well as international entomological societies. The theme of the meeting, 'Metamorphosis – a new beginning', expressed the overall organizational changes the Society has implemented recently, including reorganization and renaming of the Sections.

The meeting had seven Program symposia, 22 Section symposia, 39 Member symposia, and two international WebEx symposia for a total of 70 in all. No fewer than 27 symposia directly related to biological control and pest management included:

- The changing nature of insect management in greenhouses: staying one step ahead of arthropod pests
- The changing nature of pest management for ornamentals and turfgrass

- The evolution of military entomology
- Global impact of biological invasions: transformation in pest management approaches
- Pollen and nectar-providing plants enhance biological control with parasitoids and predators
- Legal and collaborative challenges between industry, universities, and IR-4 that impact product development successes
- Current research and developments of new insect repellents
- Forest entomology: changes impacting our discipline
- Light brown apple moth (*Epiphyas postvittana*) – a new quarantine problem
- Organics strategum efficacy: so many choices, so little time
- The impacts of genetically modified organisms in entomology (*student debate*)
- Entomology without borders – the next stage in resistance management
- Metamorphosis of vineyard pest management
- Tick genomics and beyond – new advances in tick-borne disease systems
- Environmental fate of transgenic insecticidal proteins from genetically-modified crops: the metamorphosis of ecotoxicology
- Phlebotomine sand flies in public health: metamorphosis of research from basic biology towards novel disease control strategies
- Overlooked areas of concern for pest solutions
- Stalk boring lepidopteran pests in multi-crop ecosystems of the United States: current status, challenges, and prospects
- The global threat of red palm weevil (RPW), *Rhynchophorus ferrugineus* (Olivier), to major palm species
- An entomological perspective addressing challenges in the developing world: new frontiers in food and bio-security
- Advances in weed biological control: the on-going metamorphosis
- From North American pest to European threat: 21st century western corn rootworm management at home and abroad
- Challenges in managing western flower thrips
- New perspectives on stink bug biology, ecology, behavior, and management
- School integrated pest management
- Managing soil arthropod pests in vegetables: high stakes and long odds
- Stored product insect pest management: decades of change, recent advances, and challenges for the future

Also, a great number of ten-minute papers and posters presented a wide diversity of current research from the entomological and acarological community. All presentations were recorded and are now freely accessible on the ESA website (www.entsoc.org) to those who registered for the meeting and soon to be freely available to all ESA members.

The Linnaean Games drew media attention for the first time, with an article entitled 'Bugs, brains and trivia' that was featured on the home page of Smithsonian Magazine's website. Ten teams participated, but it was the team from the University of California, Riverside that prevailed to become this year's champion.

The 2009 meeting will be held in Indianapolis, Indiana, on 13–16 December. The theme, 'Celebrate entomology: colleagues, science, and ideas' will aim to "disseminate original research and perspectives leading to a continuous stream of discoveries and applications relevant to the science, and create productive opportunities to stimulate new ideas and capitalize on the diversity and varied perspectives of the membership".

By: Ronald D. Cave, University of Florida.

Workshop Gives Green Muscle the Green Light

Two years ago, in February 2007, a workshop was held in Saly, Senegal to discuss how the biopesticide Green Muscle®, based on spores of the fungus *Metarhizium anisopliae* var. *acridum*, could be developed to control desert locusts (*Schistocerca gregaria*) at an operational level. That meeting recommended further research to fill in knowledge gaps, action to ensure availability and quality of the biopesticide, and other, information-based, activities. The overall objective was to promote rapid integration of Green Muscle® into operational desert locust management, especially in the area of preventive control.

Two years later, the Second International Workshop on the Future of Biopesticides for Desert Locust Management was held at FAO (Food and Agriculture Organization of the UN) in Rome, on 10–12 February 2009, to summarize activities undertaken since the first workshop and to produce new recommendations regarding the future use of Green Muscle®.

The five presentations on the first day of the Rome workshop provided an update on progress since the last meeting. The first, 'Review of results from the latest research' (James Everts, FAO) indicated that Green Muscle® is working well in trials. Locusts, although not killed immediately, appeared to stop feeding after 24 hours; an accurate record of number of locusts killed by the biopesticide could not be obtained owing to a high level of predation (mainly by birds) on the infected locusts.

The second presentation highlighted how Green Guard® (the Australian product based on another isolate of the same fungus) was used to control the tropical migratory locust (*Locusta migratoria*) in Timor Leste in a 2007 outbreak. As the only way to spray the infected area was by aerial application, what proved to be a highly successful and organized 'PR' exercise was the first step. This informed local residents about what was going to happen and explained why they should not to be worried by the helicopter that would fly overhead, and also how the effects of Green Guard® would differ from those of chemical pesticides. Not only did Green Guard® work well against locust hoppers on the ground but flying adult swarms were also sprayed and effective controlled was gained.

The third presentation looked at the external costs of chemical pesticides using a framework to identify and apportion these. It also demonstrated the effects of some chemical pesticides on human health (e.g. 29 people died owing to effects of chemical pesticides from 2003–2005 in Senegal). Estimates indicated the external costs of chemical pesticides in 2003–2005 in Senegal to be over €8 million at 2007 prices. This figure was broken down to produce an impact cost for certain pesticides used in locust control. For example, malathion 960 UL, the most commonly applied pesticide in the campaign, had an estimated external cost of €25.76/ha whereas Green Muscle®'s external cost was only €0.12/ha.

The fourth presentation (Ken Neethling, BCP, South Africa on behalf of Green Muscle® producers) outlined work that had been done by BCP to improve formulation, and described how the decision to return to a powder formulation (TC – technical concentrate) had been made. His talk emphasized how more sales of Green Muscle® would result in a fall in price through economies of scale. He also suggested that the recommended dose of 50 g/ha could be reduced to 25 g/ha or in some case even 12.5 g/ha, which would drastically reduce the cost of biopesticide treatments.

The final presentation, 'Green Muscle: working towards a new practical licensing agreement for 2009 and beyond' (Joan Kelley, CABI) described progress in changing the LUBILOSA Trust Agreement between the producers of Green Muscle® and the donors, work being carried out with ISIS Enterprise who are acting as intermediaries.

On the second day, participants split into three working groups. Group 1 discussed 'The potential for the present biocontrol products to be used in desert locust control'; Group 2 discussed 'Expanding the demand and production for Green Muscle® in the locust affected countries (and other regions)'; and Group 3 discussed 'Current status of biopesticides – where are we now?' The groups were tasked with coming up with recommendations, which were presented on the final morning of the workshop, and were then discussed and rationalized (as some recommendations emerged from all three groups); a final set of recommendations from the meeting were agreed in the afternoon.

The ten recommendations from the meeting were divided into three categories: using Green Muscle® operationally; promotion; and resources. In summary, it was recommended that:

- Green Muscle® should now be used operationally and there is no further need for trials to be carried out.
- Promotion of Green Muscle® is required at all levels, from government down to the farmer level; the framework on external cost of chemical pesticides, presented in this meeting, can be used to argue the case.
- Some further resources are needed to facilitate good operational use of Green Muscle® and, therefore, successful control campaigns.

By: Belinda Luke, CABI.

New Books

Two New IPM Volumes

Two volumes on integrated pest management edited by Rajinder Peshin and Ashok K. Dhawan were published by Springer in March 2009, with print and online versions available. The first focuses on the 'Innovation–development process' while the second deals with 'Dissemination and impact'. A summary of the contents, given below, indicates where readers with interests in the areas covered will want to take a closer look. (For a flavour of one chapter of Volume 2, see: 'How to collaborate with farmers on IPM research' in the Training News section, this issue.)

Volume 1 contents[1]: 1. Integrated pest management: a global overview of history, programs and adoption (Rajinder Peshin, Rakesh S. Bandral, WenJun Zhang, Lewis Wilson & Ashok K. Dhawan); 2. Integrated pest management: concept, opportunities and challenges (Ashok K. Dhawan & Rajinder Peshin); 3. Pesticides and pest control (David Pimentel); 4. Environmental and economic costs of the application of pesticides primarily in the United States (David Pimentel); 5. Economic and ecological externalities of pesticide use in India (P.K. Shetty & Marium Sabitha); 6. Advances in crop protection practices for the environmental sustainability of cropping systems (W.G. Dilantha Fernando, Rajesh Ramarathnam & S. Nakkeeran); 7. Keys to the increased use of host plant resistance in integrated pest management (Michael Stout & Jeffrey Davis); 8. Biotechnological interventions in host plant resistance (Aditya Pratap & S.K. Gupta); 9. Biological control and integrated pest management (David Orr); 10. Conventional and new biological and habitat interventions for integrated pest management systems: review and case studies using *Eldana saccharina* Walker (Lepidoptera: Pyralidae) (D.E. Conlong & R.S. Rutherford); 11. Behavior-modifying strategies in IPM: theory and practice (Cesar R. Rodriguez-Saona & Lukasz L. Stelinski); 12. Botanicals in pest management: current status and future perspectives (Sanjay Guleria & A.K. Tiku); 13. Insect outbreaks and their management (T.V.K. Singh & J. Satyanarayana); 14. Plant disease epidemiology and disease management – has science had an impact on practice? (Gregory A. Forbes, Eduardo S.G. Mizubuti & Dani Shtienberg); 15. Integrated disease management: concepts and practices (V.K. Razdan & Sachin Gupta); 16. When is a rice insect a pest: yield loss and the green revolution (James A. Litsinger); 17. Changing trends in cotton pest management (K.R. Kranthi & D.A. Russell); 18. Non pesticidal management: learning from experiences (G.V. Ramanjaneyulu, M.S. Chari, T.A.V.S. Raghunath, Zakir Hussain & Kavitha Kuruganti); 19. IPM programs in vegetable crops in Australia and USA: current status and emerging trends (Nancy A. Schellhorn, Teresia W. Nyoike & Oscar E. Liburd); 20. Integrated pest management in fruits – theory and practice (Donn T. Johnson); 21. Bio-intensive integrated pest management in fruit crop ecosystem (Virender Kaul, Uma Shankar & M.K. Khushu).

Volume 2 contents[2]: 1. Diffusion of innovation theory and integrated pest management (Rajinder Peshin, J. Vasanthakumar & Rajinder Kalra); 2. Evaluation research: methodologies for evaluation of IPM programs (Rajinder Peshin, K.S.U. Jayaratne & Gurdeep Singh); 3. Protocol for economic impact evaluation of IPM programs (George W. Norton & Scott M. Swinton); 4. Economic evaluation of integrated pest management programs (Kamal Vatta, A.K. Dhawan & Rajinder Peshin); 5. Eliciting farmer knowledge, attitudes, and practices in the development of integrated pest management programs for rice in Asia (James A. Litsinger, Edgar M. Libetario & Bernard L. Canapi); 6. Implementing integrated pest management in developing and developed countries (B.M. Shepard, M.D. Hammig, G.R. Carner, P.A.C. Ooi, J.P. Smith, R. Dilts & A. Rauf); 7. Moving on: farmer education in integrated insect pest and disease management (Janice Jiggins & Francesca Mancini); 8. Impact of IPM extension for smallholder farmers in the tropics (Jeffery W. Bentley); 9. Impact of IPM programs in Asian agriculture (Kevin D. Gallagher, Peter A.C. Ooi & Peter E. Kenmore); 10. Evolutionary revolution: implementing and disseminating IPM in Indonesia (Edhi Martono); 11. Principles and methods of rice lepidopteroid pest and its enemy management (PEM) program in North Vietnam (Eugeny S. Sugonyaev); 12. Challenges of integrated pest management in sub-Saharan Africa (Arnold van Huis); 13. Evaluating dissemination and impact of IPM: lessons from case studies of potato and sweetpotato IPM in Peru and other Latin American countries (Oscar Ortiz, Jürgen Kroschel, Jesús Alcázar, Ricardo Orrego & Willy Pradel; 14. Integrated pest management in Europe – history, policy, achievements and implementation (Bernd Freier & Ernst F. Boller); 15. IPM programs in Commonwealth of Independent States and Russia (Eugeny S. Sugonyaev); 16. Dissemination and impact of IPM programs in US agriculture (Kristopher L. Giles & Nathan R. Walker); 17. Advances with integrated pest management as a component of sustainable agriculture: the case of the Australian cotton industry (Gary Fitt, Lewis Wilson, David Kelly & Robert Mensah); 18. Impact of IPM and transgenics in the Chinese agriculture (WenJun Zhang and Yi Pang); 19. Can transgenic crops and IPM be compatible? (George B. Frisvold); 20. Integrated pest management, biofuels, and a new green revolution: a case study of the American Midwest (John H. Perkins).

[1]Peshin, R. & Dhawan, A.K. (eds.) (2009) *Integrated pest management. Volume 1: Innovation-development process*. Springer, 690 pp. Hbk ISBN: 978 1 4020 8991 6; Price US$259. Online ISBN: 978 1 4020 8992 3; Price US$25 per chapter.

[2]Peshin, R. & Dhawan, A.K. (eds.) (2009) *Integrated pest management. Volume 2: Dissemination and impact*. Springer, 634 pp. Hbk ISBN: 978 1 4020 8989 3; Price: US$259. Online ISBN: 978 1 4020 8990 9; Price US$25 per chapter.

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